Aalto University
School of Science
Degree Program of Computer Science and Engineering

Modeling workflows for Laboratory Information Management Systems

Master's Thesis

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ABSTRACT OF
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This thesis is written in conjunction with the creation of a new Laboratory Information Management System (LIMS) aimed at small and medium sized laboratories at Whitelake Softwarepoint Oy. The goal is to evaluate the suitability of User-Centered Design (UCD) in the development of a LIMS platform and the use of Storyboards for modeling the workflows for it. In order to evaluate the suitability, four customer organizations were targeted during the research phase in which interviews and observations were used as the method of gathering data. The data was then analyzed according to the principles of Contextual Design, culminating in Storyboards proposing generic workflows for the targeted laboratories. It became clear that both UCD and Storyboards had their uses in developing a new LIMS, especially regarding communication to and from customers and within the organization developing the LIMS.

(english)

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Det här slutarbete är skrivet vid sidan av ett projekt vid Whitelake Software Point Ab med avsikten att skapa ett nytt, web-baserat, Laboratory Information Management System"(LIMS) som är riktat åt små och medelstora laboratorier. Målet i detta arbete är att utvärderä användbarheten av användarcentrerad design samt storyboards i utvecklingen av LIMS, samt användningen av storyboards för att skildra arbetsflöden. För att uppnå detta mål, undersöktes genom intervjuer och observationer fyra kunder av Software Point som har äldre generations LIMS i bruk. Den samlade informationen var sedan analyserad enligt principerna i Kontextuell Design och storyboards som avbildar vissa grund arbetsflöden var skapade. Både användarcentrerad design samt storyboards visade sig vara av nytta för utvecklingen av LIMS, speciellt då det gäller kommunikation till och från kunder och inom den utvecklande organisationen. (swedish)

Nyckelord:	LIMS användbarhet, arbetsflöden, prosesser i laboratorier
Språk:	Engelska

Contents

Abbreviations and Acronyms

UCD	User-Centred Design
CD	Contextual Design
R&D	Research and Development
QA	Quality Assurance
LIMS	Laboratory Information Management System
ERP	Enterprise Resource Planning
QC	Quality Control
HCI	Human-Computer Interaction

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This thesis is the result of six months of research and analysis at Softwarepoint and their customers.

In the beginning I was not sure where it was headed and the writing of the thesis itself took became a second priority to the research and analysis I was doing. Once the analysis was done I finally formed a clear picture of the thesis which I then followed over three months of writing and additional analysis. I would like to thank Softwarepoint Oy and especially Raimo Oinas for giving me the opportunity to do this thesis and their support throughout the process. Mr. Oinas feedback proved to be a valuable asset during the analysis of the research data.

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Sami Huoman

1 Introduction

This master's thesis is done in conjunction with a project at Whitelake Software Point Oy that aims to create a new Laboratory Information Management System (LIMS) configuration for small and medium sized Quality Assurance and Service laboratories. The current LIMS software are of a toolbox type, where the LIMS providers create configurations with the help of the LIMS that fit the target customer (Oinas, 2012). Because of this, there are some limitations to the systems themselves. The configurations of the systems are done customer-centric, but the creation of LIMS are done based on experience or based on accumulated feature requests from customers. The focus on creating a LIMS is therefore on creating a toolbox for the developers that translates into a usable end product for the users (Oinas, 2012). A similar trend can be observed in the related Enterprise Resource Planning (ERP) systems. In order to create a system that can be seen usable from a user point of view, a user study was conducted in four companies in Finland and Sweden (and additionally one pilot study in Finland). This user study will be used as a basis for modeling workflows with storyboards in the new LIMS. Both the usability of user-centered design and using storyboards to model workflows when designing a LIMS will be evaluated and pursued in this thesis. The approach to User-Centred Design (UCD) in this thesis will be Contextual Design (CD), explained in chapter 2.

To understand how to model workflows, one first needs to understand what a workflow is. Cambridge University's online dictionary (Cambridge Online Dictionary) defines a workflow as: "The way that a particular type of work is organized, or the order of the stages in a particular work process." The implication of this, in software engineering, would be that workflow modeling is concerned with depicting the whole work process and not only the computer interaction or only the general workflow, where the computer interaction is just another step. This is further supported by Lassen (2008), who points out that workflow is a term that can hold a different meaning depending on who one asks. Furthermore, he defines workflow as:

> *..how resources work on tasks in a process. Resources are intended to be understood in the most general form, so a resource can be a computer, a person, or a device – essentially anything that can be used to carry out a particular task. A task can be any kind of job, such as printing a document, or filling in some information in a form. (Lassen, 2008)*

This definition is more accurate, especially for software engineering and UCD because it focuses on how "resources" work on tasks, and does not only have a generic focus on the task itself. For the different modeling approaches available in CD, the implication is

that even though sequence models, flow models, artifact models, culture models, as well as physical models create a comprehensive picture of a workflow, it becomes complex. Furthermore it will not be possible to change the culture or physical layout of laboratories in this case. That leaves flow, artifact, and sequel models as a complex way to depict the workflows (complex in the sense that it requires three models to get a good overall picture). This thesis will therefore use Storyboards as the method of depicting workflows. A well executed storyboard will have the elements of the above three models present, as well a better implication of the physical space and the laboratory culture than these. The three models will be used as the base for the storyboard, in their consolidated form.

1.1 Problem Statement

The requirements from different types of laboratories are different. Not only do the requirements differ between laboratories, but also the requirements between the types or the size of laboratories. Software Point divides the laboratories into three different types: Research & Development (R&D) laboratories, Quality Assurance (QA) laboratories, and Service laboratories (Oinas, 2012). Out of these laboratories, the project on the side of which this thesis is written, is one that aims to create a new, modern web-based LIMS for small and medium sized QA and Service laboratories. The LIMS should replace existing older generaion LIMS while maintaining the functionality in them.

R&D laboratories have a lot of different processes and creating a LIMS suits them all will be difficult. Big laboratories are exempted as they appear in big organizations where there are additional requirements of having the LIMS fit with other systems and the general work environment. Small and medium sized QA and Service laboratories are homogenous enough to create a configuration that could fit them all. The main difference between these two types of laboratories is the need for billing (QA laboratories do not need billing, while Service laboratories do). Additionally, in QA laboratories the customers are inside the organization in question.

Traditionally the focus of LIMS systems has been on implementing the functionality that is needed by the customers (Prasad and Bodhe, 2012) and not the usability of the system nor the pleasantness of use for the end user (Prasad and Bodhe, 2012; Ulma and Schlabach, 2005). There has been a toolbox with existing features that can then be tailored to suit the user needs. The problem therewith is that it forces a certain User Interface (UI) paradigm on the users that is, at least in some ways, inefficient and difficult to use (Oinas, 2012). When creating a new LIMS, there is a unique opportunity to address some of the bigger problems there are with the existing systems that are in use today in small or medium sized QA or service laboratories. In order to create a system that can be seen as usable, and not suffer from the issues by the two older systems which

the new system aims to replace, the user studies are conducted in conjunction to this thesis attempt to bring a User-Centered Design (UCD) perspective into the design of the system and especially the UI by modeling the workflows based on the findings. The user studies will additionally help to map out what are the the good and usable parts of the older generation LIMS interfaces and what are the existing problems that can be improved with a modern UI.

The goal is to have an UI in the end of the project that creates an optimal workflow and supports general laboratory workflows as well as possible and not one that forces an inefficient workflow onto users. For this thesis, the goal is to evaluate the suitability of User-Centered Design for LIMS development as well as evaluate Storyboards as a mean to model workflows for LIMS development.

1.2 Scope of the Thesis

The users studied will represent a small sample of the type of laboratories that the new system is aimed at. This means that the first requirement for the studied companies is that they have to have a small or medium sized laboratory. Secondly they should primarily be a QA or Service laboratory. The users studied within these organizations cannot securely be stereotyped based on the findings. While it is true that in laboratories there is always someone who registers and analyses samples and someone who at least to a certain degree oversees the work and does reporting, the other parts of the processes might change a lot depending on the laboratory (Terho, 2012). The roles themselves might be more or less pronounced in the day-to-day work. Therefore the type of the laboratory and the LIMS used is more important than the type of the users.

The number of users interviewed or observed can be seen to range from nine to over ten. Nine users were interviewed, but if one adds the users who were not interviewed and only observed, the number lies over ten. Because of the small number of users, one cannot draw definite conclusions from wishes, difficulties or usage patterns that are only observed in one place. If, however, the same trend is observed in more than only one place, then it is reasonable to assume that it is something that should be taken into account during the design of the system.

Furthermore, this thesis will not go past modelling workflows nor will it focus on making statements regarding the requirements, even though some new requirements were unearthed during research. The new requirements will be explicitly be explained in a separate report. The goal of the thesis is to explore the user-centered design process' validity for LIMS development and the subsequent usability of the modelling techniques that come from the analysis of the research results, as well as the suitability of storyboards in LIMS development.

2 Usability and user-centered design

In this chapter the basics of usability will be presented, and the supporting methods relating to creating systems with high usability. At first there will be a brief introduction into usability and followeb by an introduction into User-Centered Design.

2.1 Usability

Usability can be seen as the ultimate goal of human-computer interaction (HCI), which is focused on studying, planning and designing the interaction between humans and computers (Carroll, 2009). HCI has many roots, perhaps most prominently psychology, physiology and requirements engineering which all aim at understanding the users and the human way of interacting with system, and based on this understanding create something that better suits the users' needs (Carroll, 2009).

HCI can be seen as having four principal factors (Benyon et al., 2010):

- People
- Activities
- Contexts where the interaction takes place
- Technologies (Hardware and Software)

These four factors, PACT for short, are essential in the definition of usability as usability engineering can be seen as the activity of trying to strike a balance between these four factors (Benyon et al., 2010). Jacob Nielsen, who has been one of the early influencers in usability has provided us with one of the earliest definitions of usability as well as the ways to measure usability. Nielsen defines usability as:

> *Usability is a quality attribute that assesses how easy user interfaces are to use. The word "usability" also refers to methods for improving ease-of-use during the design process (Nielsen, 1993).*

Furthermore, he defines usability as consisting of five different components, which all need to be satisfied in order for a system to be usable. The components are:

- *Learnability:* How easy is it for users to accomplish basic tasks the first time they encounter the design?
- *Efficiency:* Once users have learned the design, how quickly can they perform tasks?

- *Memorability:* When users return to the design after a period of not using it, how easily can they reestablish proficiency?
- *Errors:* How many errors do users make, how severe are these errors, and how easily can they recover from the errors?
- *Satisfaction:* How pleasant is it to use the design?

Despite seemingly giving a comprehensive description of usability, Nielsen fails to take into account one of the central aspects of usability: Context. The ISO standard definition for usability does take this into account:

> *The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use (ISO, 1998).*

Both Nielsen's and the ISO standard definitions are needed as context is an important factor in usability, as the context will dictate how a system is used in reality and the context of use might influence the requirements. On the other hand, the ISO standard fails to take into account learnability and memorability, or at least differentiate it from efficiency and effectiveness. It might be that a system is efficient to use once a user memorizes all short-cut combinations, but the learnability or memorability of such a system can be debated. As can also be seen from the HCI definition from Benyon et al. (2010), usability is not just something that takes the system itself into use either, but it's something that bridges towards user centered design and ergonomics as not only the system itself should optimally be considered in usability, but also people and technologies. Based on these early descriptions, Benyon et al. (2010) have provided one of the more comprehensive description of a usable system:

- It will be efficient in that people will be able to do things using an appropriate amount of effort.
- It will be effective in that it contains the appropriate functions and information content, organized in an appropriate manner.
- It will be easy to learn how to do things and remember how to them after a while.
- It will be safe to operate in the variety of contexts in which it will be used.
- It will have high utility in that it does the things that people want to get done.

2.1.1 Usability in LIMS

LIMS are not known for their focus on usability (Metrick, 2010), despite the claim from Prasad and Bodhe (2012) that the focus has been on user friendliness since 2009. The particular difficulty in this case is the lacking literature regarding usability and LIMS. There are currently no academic articles that could be found on the subject (at least not through Google Scholar or the ABI inform database) by using the most obvious search terms, such as "LIMS usability" or "laboratory work processes" or "workflows". There is some literature on laboratory work processes (Skobelev et al., 2011, e.g.), but they are scarce and often citing sources that cannot be followed by the author of this thesis because of language they are published in. The current problems presented in this thesis have been gathered through interviews with people with more than ten years of LIMS experience each as well as through some rare writings from other industry specialists. In the end of this sub chapter there will be a look at usability issues in similar systems like LIMS.

Traditionally the LIMS industry has been focused on the features and functions of a system, coupled with an UI that follows the design standards (Oinas, 2012). This is a problem that also industry specialist, Gloria Metrick, has pointed out in her blog (Metrick, 2010). However, the issue of usability itself has been a non-issue as most people using the system have learned how to use it, and have not questioned how it works. Sometimes new technologies offer new possibilities, but the adoption of said technologies has been slow. A good example is the switch from desktop clients to web based UIs. This allowed the LIMS to be installed on a server, while being accessed from a browser. Now it was only necessary to have a basic computer with a browser, and not a custom-installed client on each. Another technology that has the potential to improve the usability of LIMS is tablets (Oinas, 2012). It could potentially allow the laboratories to move to a completely electronic age, without the need for papers. It does have some limitations though, namely in the case of dangerous chemicals which require safety equipment that makes the interaction with the tablet difficult or potentially harmful for it in the case of spills as the laboratory personnel pointed out during the user research. Usability in LIMS is also tightly coupled with the customer service the company providing the LIMS (Oinas, 2012). The LIMS framework might have its limitations, but it cannot be the only limiting factor for usability in LIMS. Here is where the customer service comes in and especially finding out the particular needs of the users. Laboratories have well-defined processes with many requirements (Skobelev et al., 2011; Paszko and Pugsley, 2000), and it leaves little room to maneuver in terms of usability for the developers (Oinas, 2012; Terho, 2012). However, the interaction with the customers is mostly done through the laboratory-chief or another person who is in a managerial position (Terho, 2012; Rasmussen et al., 2007), giving the developers a one-sided view on what are the needs of the customer and how

to implement them (Terho, 2012). Therefore it would also be important to interview and observe end-users as they work to get a better picture of what is being done in the case of LIMS configurations for single customers. The framework limitations are trying to be addressed by creating a framework that is closer to the targeted customer's needs in the case of the project in conjunction to which this thesis is being written.

Calisir and Calisir (2004) found in their study on ERP systems, that the difficulty of using the systems has an impact on the perceived usefulness of the systems. The perceived usefulness, on the other hand, has a great impact on customer satisfaction. Moreover, the learnability of ERP systems also impact end-user satisfaction. Some specifics regarding what improves the learnability and perceived ease of use of ERP systems include the removal of unnecessary screens as well as a broad menu of selections (rather than only a few menus with many options) (Thong et al., 2002). Shortcuts for often used features were also factors that were appreciated among end-users.

The research from Babaian et al. (2006) regarding the validity of designing collaborative ERP systems rather than systems that are used as tools in user to user communication provide some valuable insights in the problems regarding ERP systems. They argue that by improving the usability of ERP systems has a great impact on user satisfaction, the productivity of the users and therefore also monetary implications for the customer companies. Usability is also not only restricted to UI implementation, real usability has to be designed from the start, and in their school of thought, the focus should lie on making systems more collaborative.

Steinlechner and Parson (2001) developed a LIMS for their own laboratory. The result of this development provides encouraging results regarding using UCD for developing a LIMS platform. Considering they were intimately familiar with their own processes they managed to create a system that optimized workflow and minimized paperwork for the laborants. It should, however, be noted that they created a LIMS that suited exactly their own need and not the need of other laboratories. Additionally their LIMS was not a complex one in comparison to the requirements of a full-fledged LIMS. It is, however, interesting to see that they managed to show the workflow and give an overview of the whole system in a compact picture. Additionally, the internal literature within Software Point as well as results suggested by Skobelev et al. (2011) and Paszko and Pugsley (2000) makes it clear that the workflows in laboratories are well understood as well as the central functionality in LIMS (Skobelev et al., 2011). Figure 1 shows a typical LIMS workflow, which starts with a sample request and the collection of a sample and ending with the reporting of the results. Figure 1 is slightly misleading though, as it seems to suggest a limited role for the LIMS as only a simple interface to the database that stores the results while it is in fact a depiction of the LIMS workflow. The process depicted is, however, one that coincides with the internal Software Point understanding of the laboratory process

as well as the depiction from Skobelev et al. (2011).

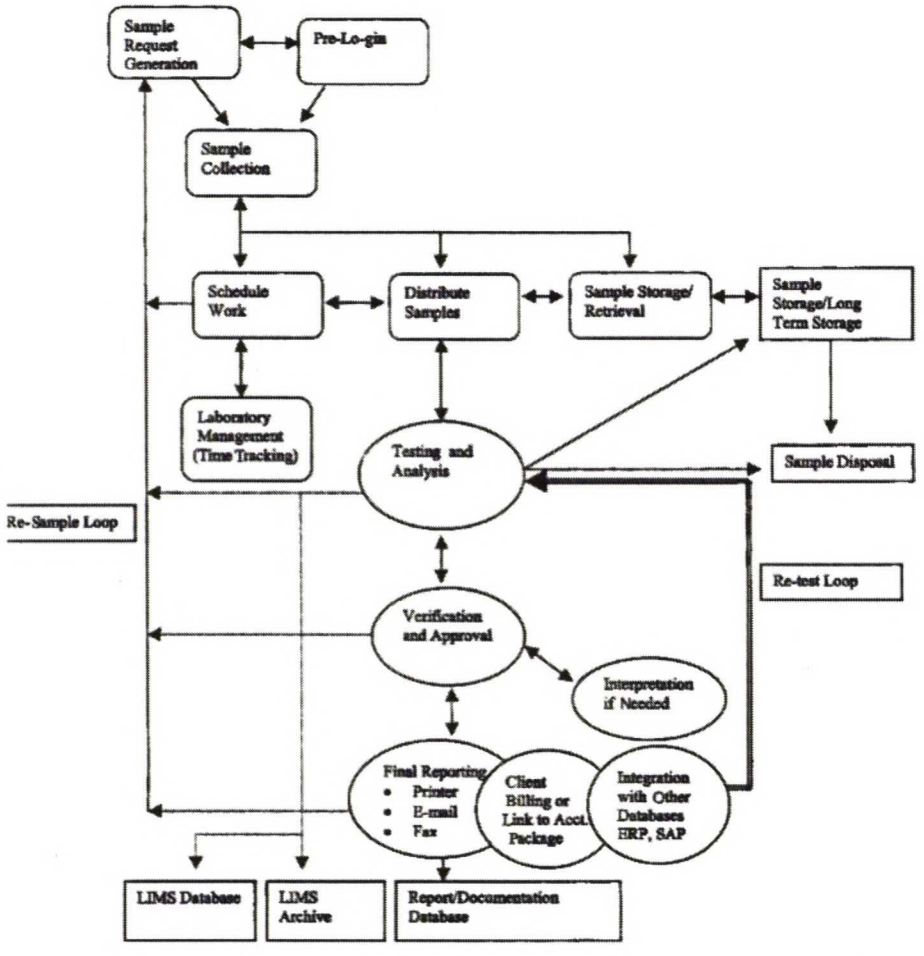

Figure 1: Schematic representing typical LIMS workflow. (Paszko and Pugsley, 2000).

2.2 User-Centered Design

Usability, like any quality practices, requires testing (Nielsen, 1993). But in order to do as little of the costly and slow testing, while still assuring that the quality of the system is not compromised, one relies on well executed requirements engineering and design. This is true as well for usability. Fixing usability problems after they are implemented is costly. Fixing them during the design phase is cheap (Boehm and Basili, 2001).

In order to tackle the aforementioned problem with usability, interaction designers, user experience designers and other usability professionals tend to rely on UCD. In UCD the users are in a central role as the needs are tried to be taken into account through different techniques. Moreover, the aforementioned PACT framework allows for a design principle involving the users. The theory is that technologies enable the users to do things. The

activities done by the people are then, on the other hand, requirements which need to be implemented by technology. There is essentially a tie between the behavior of people based on technology and technology supporting the people's behavior. This is illustrated in Figure 2 (c.f. Benyon et al., 2010).

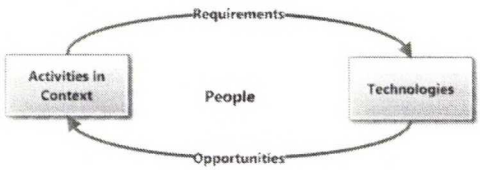

Figure 2: PACT diagram (c.f. Benyon et al., 2010)

There are three different approaches to UCD:

- Cooperative design (Boedker et al., 2000)
- Participatory design (Muller and Kuhn, 1993)
- Contextual design (Beyer and Holtzblatt, 1999)

Cooperative design is a traditional design approach which stems from Scandinavia (Boedker et al., 2000). It emphasizes the role of the user as a part of the design team and in it users are seen to be on equal footing as the designers. Because of the equal footing, it requires considerable effort from the users' part, but with great potential gains. The problem with this approach lies in that a few users might influence the system too much (in the case they are only representatives of a larger user base). This approach can be seen as one of the pioneers of UCD and the more or less de facto standard of involving thirteen users at some point in the design phase can be credited to cooperative design (Boedker et al., 2000; Muller and Kuhn, 1993).

Participatory design is a form of UCD, where the end users and other stakeholders are involved in different degrees in the design process (Muller and Kuhn, 1993). It is a North-American (or anglosaxian) twist on cooperative design. The focus lies on involving the different stakeholders in the design process, but it is not emphasizing the involvement of stakeholders on equal terms. The involvement of the users can vary between having stakeholders test the designs (acceptance testing), having the users as the basis for requirements engineering and other variations requiring a closer relationship, nearing the cooperative design process. Because of cultural differences the relationship is not as involved as in cooperative design and the user end up having a more passive role (as a source of information, but not as a part of the design team) (Boedker et al., 2000).

Contextual design is an approach where the focus is on the customers, and finding out their needs through different techniques. It is influenced by participatory design,

but the customer and users have a more passive role here than they would potentially have in participatory design (Beyer and Holtzblatt, 1999). This approach is based on anthropology, psychology and design (Holtzblatt and Beyer, 2011). The assumption is that the end-users are experts at what they do, but they do not have capacity to express in an adequate way for system design. This leads to a relationship with the user that is closer to participatory design than cooperative design. The basics of anthropology requires the designer to observe the user in the actual context of work (hence the name of this approach) and this is one of the cornerstones of contextual design. The methodology at the context is one where the designer aims to understand the user and his work. The way to do this is to create a certain master and apprentice relationship with the user, where the user is the master (Beyer and Holtzblatt, 1999; Benyon et al., 2010).

In this user study and the following analysis and design, the research and following analysis has been based of contextual design. The approach has been that of contextual design and it will follow contextual design principles, but because of the restrictions in the accessibility to the users and time at hand, some shortcuts had to made (contextual design is an explicit process). The actual methods for design will be presented in chapter 4 and the description of the methodology in this user study can be found in chapter 3.

2.3 Defining the users

In order to conduct a successful user study, one needs the right users. Who the right users are, is highly contextual, but Holtzblatt and Beyer (1998) suggest picking two to three users for each role that is relevant to the study and studying four to six different organizations. According to them, it is also adamant that all the different stakeholders are heard in the study, in order to create a system that best supports the organization, not only one user.

Additionally, Hyysalo (2009) suggests that the partners of companies are the leading authorities on the subject matter, who have a good general picture. They do however lack an accurate view on how work is actually done. Therefore Hyysalo (2009) suggests that a much more useful group to collaborate with is the "lead users". These users have the experience and vision needed for creating a new system, as well as the motivation to improve their tools. It should, however, be noted that the lead-users and the leading authorities are not representative of the big mass of end users and therefore the ideas should at least be tested with the main users or at least the "crucial users" (users who are key for spreading the software, but are not dependent on it and would therefore not use it if it had bad usability)(Hyysalo, 2009).

The users in this study were picked based on three different criteria. The first criterion is regarding the LIMS they are using. There are two older generation LIMS that are to

be replaced by the new LIMS described earlier in this thesis. Both systems (refered to as System 1 and System 2 later in this thesis) have to represented. The second criterion is the type of laboratory being investigated. Ideally there should be as many QA laboratories as Service laboratories. The third criterion is cooperation. The customers should be open and provide us with the opportunity to visit them and to follow the users in their real work environment.

Inside the different organizations optimally all different kinds of users that are interacting with should be available for study, also those who are indirectly dependent of it. In a laboratory environment there are two to four different stakeholder-types who are using LIMS and then one to three stakeholder-types who are indirectly impacted by the system. The actual realization of the study is described in chapter 5.

3 Methods for user research

In this chapter the different approaches for conducting user studies will be presented. The approach dictated by Contextual Design is that of Contextual Inquiry (Beyer and Holtzblatt, 1999). Because of limitations regarding time and availability of users to follow, the general principles of regular interviews and observations will be presented here as well.

3.1 Interviews

Interviews are one of the most common and efficient method of gathering requirements from stakeholders (Rogers et al., 2007). It simply involves meeting a stakeholder and talking to him or her while having certain goals set regarding what the discussion circle around, how to achieve them and with whom.

There are three different ways of conducting an interview (Benyon et al., 2010; Rogers et al., 2007). One is to have a structured interview, in which case the questions for the interview are written beforehand and the questions are asked exactly how they are written (Benyon et al., 2010; Rogers et al., 2007). This restricts the interviewer from getting detailed replies as the range of answers are limited. This type of interviews are used when the type of answers lie within similar limits as in questionnaires and the time set for an interview is limited (Rogers et al., 2007).

Another type of interviews is semi-structured interviews. These interviews have prepared questions as well, but the wording of the questions is up to the interviewer and it also allows the interviewer to follow up on questions if the provided answers are inadequate or something interesting is mentioned that seems worth exploring (Benyon et al., 2010; Rogers et al., 2007). The wording of the questions is also done in an open-ended manner

(there is no limited set of answers).

The third type of interviews are unstructured interviews. This type only has a set topic and no pre-formed questions, but it requires some additional preparation from the interviewer, like getting familiar with the subject. These can be used if the interviewer wants to avoid having any pre-conceptions about a subject and if he wants to explore the subject with the interviewee and learn more (Benyon et al., 2010; Rogers et al., 2007).

Additionally to just asking questions, one can also add some additional elements into the interview session (Benyon et al., 2010). These can include stories and scenarios as well as prototypes. This can help the interviewee to get a better picture of what they are asked to discuss and share their thoughts on (specifically if the product in question is already partially envisioned or it is to be an improvement of existing products). It should also be noted that, even though interviews do allow getting detailed information from the interviewee, the quality of that information can be of dubious quality. If, for example, asked about daily routines, there might be several things that the interviewee forgets to mention simply because he or she does not think about it (Benyon et al., 2010; Rogers et al., 2007).

Furthermore, Robson (2002) suggests a structure for interviews that starts with an introduction where the interviewer states the purpose of the interview, explains what the gathered data will be used for and potentially asks if the interviewee agrees to be recorded. The second step in an interview is the "warm-up" session where the interviewer asks some general questions and tries to get to know the interviewee a bit better and his or her role in the organization (if applicable). The third step Robson (2002) suggests for an interview is the actual interview where the actual questions are asked, the more in-depth questions should preferably come at the end of the interview, assuming it fits logically. The fourth step is a "cool off period" as Robson calls it. He suggests asking some more simple and non-threatening questions at the end to leave the interviewee relaxed. In the "closing off" step the interview ends and the interviewee is thanked for his participation. Holtzblatt and Beyer (1998) additionally suggest summarizing findings at the end of the interview in order to validate the results.

3.2 Observation

Observing people while they are doing activities relevant to the product being developed is a time consuming, albeit detailed way of finding requirements (Benyon et al., 2010). The information in interviews can be false or incomplete and therefore observations of users are a good way to complete the research. Through observations one can see the small things in the activities of the user that would else have not been found out. On the downside, during the observations one cannot find out what is going on inside the

head of the user, which means that the observations could be combined with an interview after the observations are done, asking the user why he did something in a specific way (Benyon et al., 2010) or by asking the user to think aloud (Rogers et al., 2007).

There are three different types of observations avaiable: Direct observations in the field, direct observations in a controlled environment, and indirect observations (Rogers et al., 2007). Direct observations in the field is the perhaps the most common way of doing observations in a planned manner. The observations are done in the context of the work and have therefore all the benefits and downsides explained above. The challenge is to focus the observations (without getting sidetracked) and to get the relevant information out of it (Rogers et al., 2007; Benyon et al., 2010). Rogers et al. (2007) suggest having three different things in mind for the observations:

- *The person. Who is using the technology at any particular time?*
- *The place. Where are they using it?*
- *The thing. What are they doing with it?*

Focusing on these three things during an observation might be surprisingly effective according to Rogers et al. (2007), but one should also keep in mind the risk that the relevant observations are not made. A more complex framework is suggested by Robson (2002) where the observer should focus on the nine following items:

- *Space.* What is the physical space like and how is it laid out?
- *Actors.* What are the names and relevant details of the people involved?
- *Activities.* What are the actors doing and why?
- *Objects.* What physical objects are present, such as furniture?
- *Acts.* What are specific individual actions?
- *Events.* Is what you observe part of a special event?
- *Time.* What is the sequence of events?
- *Goals.* What are the actors trying to accomplish?
- *Feelings.* What is the mood of the group and individuals?

This framework is better suited for experienced observers who are able to pay great attention to the context of the actions of the people being observed (Rogers et al., 2007). Additionally to keeping tracks of at least the aforementioned core areas to focus on, the

role of the observer self can varies, and depending on the situation or study the observer has to pick the best solution. The role can vary from being completely passive (observing without participating in the activities) to being completely participant (attempting to become a part of the group being observed) (Rogers et al., 2007).

Direct observations in controlled environments are observations either made in conjunction with an interview (as an illustration of how the user does things) (Benyon et al., 2010) or as a more controlled observation where the activities do not happen in the actual context (for example in a laboratory) (Benyon et al., 2010; Rogers et al., 2007). The things to focus on do, however, not differ from observations in the field.

Indirect observations are observations not done by the researcher because of either the obtrusiveness of such an arrangement or because of time issues (like in a week long study) (Rogers et al., 2007). The method proposes to ask the users to write diaries about their activities or to record the users' actions in other ways (logging their interaction with the computer for example).

A different approach to observations is provided by ethnography. In ethnography the observer take an as participatory role as possible and attempts to gather as much data as possible, especially of common things and events (like what people do, how they do it, what they say) (Rogers et al., 2007). The method of collecting the data does also not matter, it can be in any form (from notes to pictures). The problem with ethnographic studies is that is takes weeks or months to gather all relevant data as it is rather opportunistic. Rogers et al. (2007) suggests the following list of materials that can be collected in an ethnographic study:

- Activity or job descriptions
- Rules and procedures (etc.) said to govern particular activities.
- Descriptions of activities observed.
- Recordings of the talk taking place between parties involved in observed activities.
- Informal interviews with participants explaining the detail of observed activities.
- Diagrams of the physical layout, including the position of artifacts.
- Photographs of artifacts (documents, diagrams, forms, computers etc.) used in the course of observed activities.
- Videos of artifacts as used in the course of observed activities.
- Descriptions of artifacts used in the course of observed activities.

- Workflow diagrams showing the sequential order of tasks involved in observed activities.
- Process maps showing connections between activities.

As can be seen in the list above, the range of items collected in ethnography is vast and the whole process is thorough, albeit cumbersome. A successful limitation of ethnography has been done by Holtzblatt and Beyer (1998) who used among other things ethnography as a base for their "Contextual Design" method.

3.3 Contextual Inquiry

Contextual Inquiries were first suggested by Beyer and Holtzblatt (1999) as a part of Contextual Design as a way to find out the needs of the users. Simply put, Contextual Inquiries are observations and interviews in the context that is relevant for the study (e.g. at the work place of the user). The important part is to be at the actual place where the relevant activities happen.

A Contextual Inquiry starts as an interview, where the interviewer asks the user whether he or she agrees with being recorded and where the practicalities are laid out and the interviewer and interviewee get to learn to know each other (Benyon et al., 2010). This should also be followed by a small introduction into the work matter.

The inquiry itself is not a traditional interview. The interviewer will follow the user while he or she is working, and observe the work being done (Holtzblatt and Beyer, 2011). If the interviewer sees something that he or she does not understand or finds otherwise interesting, he can interrupt the interviewee and ask what it is he did, why he did it etc. The goal is to try to understand the users and the work they do as well as possible. After the interview (or interviews) the interviewer should also aim to have a summarizing session, where the findings are summarized in order to assure that something was not misinterpreted (Holtzblatt and Beyer, 2011).

4 Analyzing data in contextual design

4.1 Flow Models

Flow models are used in Contextual Design to depict the work and how it is split up between different people. Each flow model has one particular entity at its center; from whose or which point of view the model is drawn. The result is that there may be many

different models, all which are more or less similar, but drawn from another person's point of view. (Benyon et al., 2010; Holtzblatt and Beyer, 1998)

The model consists of the following eight components (Benyon et al., 2010; Holtzblatt and Beyer, 1998):

- *Individuals – Who is involved.*
- *Responsibilities – What is each person responsible for?*
- *Groups – If more than one person has the same responsibilities.*
- *flow – How people communicate to get work done.*
- *Artefacts- The things that people interact with during work. Can also be intangible objects, like meetings.*
- *Topics of communications – Why are people communicating?*
- *Places – A place if it's central to work (for example a meeting room).*
- *Breakdowns – Problems in communication and coordination.*

4.2 Sequence Models

Sequence models are depictions of work tasks (Benyon et al., 2010; Holtzblatt and Beyer, 1998). These are, like flow models, made from the point of view of some particular person(s). The tasks are broken up into individual steps which are then ordered chronologically. Additionally to the task steps themselves, there are also mentions of the intent of the action as well as a "trigger", which explains why the action has started. The sequence models consist out of four different components (Benyon et al., 2010; Holtzblatt and Beyer, 1998):

- *Intent – The purpose or goal the sequence attempts to achieve. There will be one for the whole task and then additional intents for the subsequences.*
- *Trigger – What causes this task to take place.*
- *Steps – A series of actions that take place to achieve the main intent.*
- *Breakdowns – Descriptions of problems that can occur at any given step.*

4.3 Artifact Models

Artefact models are essentially depictions (copies of original, photos, videos, sketches, or descriptions) of different tools that are used to actually perform work (Benyon et al., 2010; Holtzblatt and Beyer, 1998). The tools can consist of different forms, tables, websites, computers, etc. The goal is to gather as much information regarding the actual work and its environment as possible and to find some unspoken requirements that are only apparent from viewing artefacts. An artefact model has eight components (Benyon et al., 2010; Holtzblatt and Beyer, 1998):

- The information content (what does the artefact tell the user).
- The structure of the artefact, showing potential different parts to it and who might be using what part of it.
- Informal additions to the artefact from the users (scribbles on the side etc.).
- What does it look like and how is it styles? Is the style important?
- Changes to the artefact over time.
- When was it created, what is it used for and by whom is it used?
- Breakdowns in its use.

4.4 Physical Models

Physical models are depictions of the workspace of the users (Benyon et al., 2010; Holtzblatt and Beyer, 1998). The models are not supposed to show detailed floor plans, but rather the distribution of artefacts and where the work takes place and who sits where. The thought is, that through modeling the physical workspace, there might be some insight into why work is done in a particular way. A physical model should answer the following six questions (Benyon et al., 2010; Holtzblatt and Beyer, 1998):

- What are the physical structures of the workspace (as long as they affect the way work is carried out)?
- How are people moving in the workspace? Are the artefacts moved around?
- Where are the computers and networks situated?
- Where are the key artefacts located?
- What is the layout of the workspace?
- What are the breakdowns?

4.5 Cultural Models

Cultural models are ways of representing the way things are done at work (or other places) (Benyon et al., 2010; Holtzblatt and Beyer, 1998). These things are unspoken and have to be found out during inquiries through observations. It encompasses everything from hierarchies and rules that affect the way work is done to how people interact with each other and how these interactions affect others. The cultural models consist out of the following four components (Benyon et al., 2010; Holtzblatt and Beyer, 1998):

- *Influencers – People or entities who affect the way work is being done. Can be someone or something from inside the organizations or from outside the organizations.*
- *Extent of the influence by the people mentioned above – The impact these entities have on the work being done. This can be visualized by how much the bubbles overlap.*
- *Influence direction – Arrows indicating who is influencing who, or what.*
- *Breakdowns – In this case, breakdowns caused by cultural issues.*

4.6 Affinity Diagrams

Affinity Diagrams are a way of organizing information, data and insights of the creator of the Diagram through categorization and through creating hierarchies which will eventually reveal underlying common structures and themes (Rogers et al., 2007; Benyon et al., 2010). Affinity diagrams are additionally a way of laying out the data of research without drawing conclusions of the results before the results have been reviewed and discussed by the design team (Beyer and Holtzblatt, 1993). Benyon et al. (2010) supplies a short checklist or guide for constructing affinity diagrams:

- Write each separate requirement, wish, and need on a Post-it. Try to keep the descriptions as short as possible (ideally a word or two).
- Repeat until you have several hundred.
- The affinity diagram is built bottom-up by identifying common themes and structures.
- Create the diagrams on the walls, grouping them by themes.
- Document the emerging groups and subheadings.

Affinity diagrams are not used as a part of modeling workflows or making sense of the results when initially analyzing research data in contextual design, but as a mid-step before starting with the design of the system (Holtzblatt and Beyer, 1998; Benyon et al., 2010) and consolidating the flow and sequence models done earlier. This will be true for this project as well.

4.7 Storyboards

Storyboards are another way to display tasks, in the same way like sequence models (Rogers et al., 2007; Benyon et al., 2010; Holtzblatt and Beyer, 1998). The visualization of the task is done through creating a drawing for each step in the sequence, like in storyboards used in the movie industry (Truong et al., 2006). The storyboards, particularly in contextual design, are used to assure that tasks happen like they would in the real world (Benyon et al., 2010). More traditionally, the focus in storyboards in software engineering has been on different screens and the navigation thereof (like a low-fidelity prototype) (Rogers et al., 2007), while in CD the storyboards are constructed to have a broader perspective with an additional focus on communication between users and other artefacts (Benyon et al., 2010).

Storyboards bring together the work done with analyzing study results with the different models mentioned earlier in this chapter as well as the affinity diagrams and consolidated models (in case it has been done) (Benyon et al., 2010). Because of this, it is important to understand what sort of processes go into creating one. Firstly the designer needs to discover the central tasks to this particular system and choose one of them. The second step is to go through the models generated earlier and the affinity diagrams for everything that is relevant for this particular task. After this the consolidated models can be generated and once they have been verified the storyboards can be created, depicting each step of the task (including all interactions). The UI in the storyboards does not have to be detailed. This should be done for all key tasks. (Benyon et al., 2010; Holtzblatt and Beyer, 1998)

A particular strength of storyboards, as noted by Truong et al. (2006); Brown et al. (2008); Haesen et al. (2009), is that it is a useful tool for displaying requirements for a large audience, including customers and people less familiar with software engineering and in multidisciplinary teams. They will also allow for an easier overview of the requirements for the software engineers as pointed out by (Griffiths et al., 2003) and suggested by (Haesen et al., 2009). Additionally, storyboards can contain a meta-data section which can be used for a range of stakeholders to comment on the particular requirements, without having to understand how software requirements work (Haesen et al., 2009). Storyboards also take into account contextual specialties that requirements or scenarios cannot (Rogers et al.,

2007).

In this thesis the storyboards will be drawn as a mixture between the traditional low-fi navigation and prototyping and showing the context in which they are used. The context in which the work and the order thereof is important, but so it is to understand what type of steps the users have to go through to get the tasks done on the computer. Because of the format, storyboards can bring together both the context and the suggestion for the workflow through low-fi prototypes that are purely manufactured for the purpose of indicating the workflow on the computer itself.

5 Realization of the Research

In this chapter there will be an in-depth description about how the user research and the analysis of the research was done in practice. This is done in order to get a good overview about how the data gathering was performed. The depiction of how the data was analyzed can be gotten from the next chapter, where the results are discussed, and only a quick review of the methods in Contextual Design are explained here.

5.1 Realization of the user studies

The research consisted of two different parts: User studies and expert interviews. Of these, the user studies were the part where the greatest effort and focus was. Expert interviews were used as an introduction to the subject and as source of complementary information after the user studies. In total five customers were contacted. The first customer was contacted as a pilot-test environment, where the research methods were tested. To review: The requirements for the laboratories contacted were two-fold. They had to be a small- or medium-sized QA or Service laboratory that are using one of the two systems (here named System 1 and System 2) the project in conjunction to which this thesis is written is aiming to replace. The list of things to observe or ask during interviews can be found as an appendix to this thesis in section A.

The results from the pilot company were not directly applicable to the results of this study because they are using another LIMS and cannot be considered to be a small or medium sized laboratory. The results from this study were conveyed to the person inside our company responsible for developing and maintaining the customer's system. There were four studied people inside the organization. The session started by an interview of the laboratory manager, where the goals and aim of the study was explained, lasting half an hour. The first end-user of the other LIMS was a supervising laborant, who was followed while doing his job for an hour. It was a participatory observation, where the the

user's actions were observed and questions regarding his work and tasks were asked. He was encouraged to try to explain what it is he is doing by pretending that the observer is a new employee who needs to be made familiar with his work. The next step was to follow a laborant for half an hour while she was doing her work. This session was more of an interview in the context of work, with some observations. There were not much real work to do that involved LIMS at that time. The last member who was studied was another laborant, who had a role requiring her to have an overview of the whole lifetime of the samples she was managing (she registered them in LIMS, analyzed them and reported the results). This lasted half an hour, making the total time spent at this organization three hours, as per agreement with the customer.

Two of the companies of the real study were located in Finland and two of them in Sweden. The companies in Finland consisted of a service laboratory and a QA laboratory, both using System 1. At the first Finnish company, the study focused on chemists, laboratory assistants and the secretary, which are all the organizational members there who use LIMS. The study started with an introduction to the laboratory and the people who work there followed by an interview with the chemist, lasting an hour. Following this interview, the chemist introduced the different stations and it was possible to observe different types of instruments and result entering systems while the chemist and laborants would explain their function and their work. After this in depth introduction to the work done, there was an interview with two laborants and observations of their work while they were entering results. This in-depth introduction and observations with the two laborants lasted one and a half hour. The next part was interviewing and observing the secretary while she was working. This lasted an hour. In the end there was another interview, followed by a debriefing and a discussion with the chemist, lasting an hour. The total time spent was four and a half hours, half an hour over the agreed time with the customer.

At the second Finnish company the most studied person was the administrator laborant, followed by some observations and a small interview with one of the laborant. The chemists or laboratory manager were not present and the factories were out of bounds (safety reasons). The total time spent at this organization was five hours (time between flights and as per agreement with the customer). The study mostly consisted of interviews and observations with the administrator laborant. One hour was spent observing and asking questions from one of the laborants while she was entering results. The focus was on getting a good overview of the company and how LIMS is used there. The organization is big, with facilities on different locations inside finland, where LIMS are used as well. LIMS were also used in the factories and mines at the location that was visited, but because of safety reasons it was not possible for me to visit those locations. The questions and list of things to observe were a basic list of compiled things that were thought up

before and adjusted after the pilot test. The original set of questions was thought up with the help of the Chief Technical Officer at Software Point and by studying existing LIMS implementations. The list was updated to a new format after the studies in Finland, and recompiled as a list of things that had to be found out. Earlier it was split into a list of things that should be asked in interviews and of things that should be observed, but in reality it ended up being used as a checklist of things to be found out.

The two companies located in Sweden were also a service laboratory and a QA laboratory. The studies in Sweden were conducted with the help of a member of the sales personnel from Software Point. At the first Swedish company the study was mostly focused on the admininistrator laborant, who acted as the contact person, and a member of the IT department. The laboratory manager was not available, but the laborants were observed in their work environment as well. The visit to this company took four hours, as per agreement with the customer. The first three hours were spent interviewing and discussing their current LIMS and working practices, as well as their wishes. After this an introduction to the laboratory environement was done, where the laborants were quickly observed and the admininistrator laborant explained the function of the different instruments, helpful artifacts and illustrated work practices and other practical considerations. The laborants were, unlike in other laboratories, staying at the same station throughout the day and involved no entering of results at the time we were there.

At the second Swedish company the Quality Control (QC) laborants were mostly interviewed. Some brief observations were done in the laboratory, but the engineers were not observed nor were the QA or purchase department, which were located off site. A part of the laboratory was not accessible without protective gear. The visit took two hours during which we interviewed the QC laborants, asking them about their processes. Additionally we asked them to demonstrate some things they mentioned during the interview.

Additionally to the visits to the companies, there were conducted interviews with developers and sales personnel at Software Point. The sales personnel had a good overall picture of the processes of different companies and the developers had some inside insight regarding the particular companies that had beeb visited. The interviews with the internal personnel were informal and unstructured. During the research, the interviews and observations were recorded by hand into a notebook or then notes were written directly into a laptop. It was not possible to record anything visual (for example artifacts contained confidential information) and the customers declined the opportunity. It was originally thought to record the conversations on a device, but it did not work out as expected because of technical limitations. The recording device had a limited capacity for recording audio, and after thirty minutes of recording audio from an observation the memory was full. Therefore the main documentation from the interviews was the notes

taken during the observations and interviews. The notes were mostly comprehensive enough to analyze the results without issues. In a couple of cases the results had to be affirmed by the developer who was working closely with the second Finnish company.

The number of users that were researched during the visits to companies was not optimal, but even a small number of users can be effectively studied and the results used for software development as Kinnunen and Kangas (2005) have shown. Mostly there were long interviews with the contact person. It would have been optimal to be able to conduct a more in depth study with all the users, but it was not an absolute necessity. The contact person had mostly extensive experience and understanding of the LIMS in use at their company and could differentiate between how things were supposedly to be done and how they were actually done once queried on the subject. In some cases it required asking several times because of the reasoning regarding why something is done in a particular way.

5.2 Realization of the analysis

The data was all gathered in a notebook which was then immediately (within 24 hours) recorded into a digital form a long with some initial categorization of the results. Once all data had been gathered, a software called Weft QDA was used for tagging the data with categories as qualitative analysis suggests as explained by Taylor-Powell and Renner (2003).

After the data was appropriately tagged, the flow models were formed for each of the companies, followed by sequence, cultural, and physical models with the help of the software SmartDraw. Finally the artifact descriptions were written (the artefacts were not available for studying). It should be noted that for the scope of this thesis the sequence models for all the possible actions were not created. For the purpose of this thesis the focus was on the four most common actions with LIMS: Registering a sample, entering the results from the analysis, approving the results, and reporting the results. Following this analysis an affinity diagram was created centered on these four actions and supporting categories which had emerged during the qualitative analysis which are systematically an intangible part of it all. It contained basic requirements and ideas that had emerged from the research. The diagram was then used as a basis for creating consolidated flow and sequence models. Finally after this the storyboards were created based on the consolidated models.

6 Analysis

In this chapter the findings from the user research and analysis will be presented and the results from each iteration of analysis discussed. The order will start with the first impressions of the qualitative analysis where the gathered data was organized, followed by an analysis of each model (flow, sequence, physical, cultural, artefact).

6.1 Qualitative analysis

When organizing the data from the user research, some natural categories started to emerge. These categories related to different parts of the processes which are in use at the laboratories. The categories were:

- Registering samples
- Reading results from the instrument
- Finding samples
- QA (Acceptance)
- Analyzing samples (Entering results)
- Reporting and billing
- Managing work
- Maintaining registers
- Other

It should be noted, that Entering results and Acceptance were both sub-categories of Analyzing samples and QA. These had many overlapping characteristics, but not everything relating to, for example, QA had to do with Acceptance. An example of the categorization can be found in the appendices under section B.

It became quickly apparent during the visits to the companies and the analysis of the results that the main activity in laboratories lie within four categories with one common supporting practice that seemed to be integrated into the other work. These four categories are "Registering samples", "Entering results", "Acceptance", and "Reporting and billing". That is to say, the practices that are directly related to samples and the analysis. Maintaining registers does not happen on a daily basis, therefore it will not be analyzed past a quick note regarding what is meant with this. Registers in LIMS are used for maintaining many different parameters that are needed throughout the analysis. These

vary from laboratory to laboratory, but often there are registers of analysis methods, collections of analysis methods, chemicals, customers, and billing information. These are then used when creating new samples and adding results.

The category "Other" contains general observations that do not fit into the other categories and observations regarding external programs used, that do not relate to LIMS. It also includes statistics, which is a debatable subject whether it should be included in LIMS. At the moment some basic statistics from samples can be generated inside LIMS, but as LIMS functionality is centered on creating a system that supports the sample analysis and reporting thereof, then statistics are not the main subject of focus. It should be noted that in the case of Customer 4, they used an external program for statistics and that Customer 3 expressed wishes for additional statistics in LIMS.

The category "Managing work" is one that is tightly bound to the other categories. The other four principal categories mentioned earlier are clearly separated from each other, but managing the work is closely tied to all of them. It starts when a sample is registered and has to be added to the work queue and given a priority. Currently the laboratories were using external means of giving samples a priority, even though there are ways of prioritizing work inside LIMS. The samples were also assigned to laborants outside of LIMS by paper or whiteboard. After the analysis is finished, then someone else than the analyzing laborant has to accept the results and report (can be the same or two different people). This was the practice in essentially all laboratories, although one laboratory was not enforcing it currently because they had not had a chemist to direct the work processes for a long time.

Reading and finding results are also supporting actions for the four main categories mentioned earlier. Once a sample is registered, the assigned laborant needs to find it in LIMS to see what analysis are to be performed as well as potentially some other information. Additionally, depending on the system in use, the people approving results need to look up the sample through the sample id or then potentially see it on the list of approved samples. Finding results proved cumbersome in some cases, as there was no general view in system 1 where one could search for all samples. In order to see in which state a sample was, the laborants would go into a view (for example approved samples) and then write the sample id in there. There were some other criteria through which laborants also tried to find samples (by customers or date). Reading the results was mostly done on paper if the results were available on paper. In another case one laborant would generate a report to view the results and in another one a laborant would review the results from a second, light weight and web-based LIMS.

Of the four main categories, the first one that will be discussed now is registering samples. Sample registration had many differing variations across the four companies. The only common nominator was the fact that it was done manually in at least some cases at

the laboratory itself. In company 1 this was actually the principal way of entering samples when the samples originated from an outside customer. The customer would send the sample with a request for analysis (it might have been discussed over phone what type of analysis should be done and the samples would already be registered then). If the samples originated from inside the organization, then the registration would have already been done through an internal system (not directly into LIMS, but into another similar, QA oriented system). Company 2 had a similar situation, some samples would be registered manually in the laboratory, mostly if the samples were external in nature. If they originated from inside the organization it was again entered through a LIMS system (in some cases the same, in other cases another more light weight one). As an exception, they would sometimes not enter samples into LIMS until after the analysis was done and the results had to be entered. The reason was that it was "faster" because of a limited number of computers. There were a couple of issues with the web-based LIMS where the state of a sample would change automatically if results were entered and that a lack of registers caused many different "constants" to be written differently. Company 3 had a similar setup to company 1. The only exception was that in some cases new samples and their request as well as reporting was done through shared Excel files. Company 4 used explicitly system 2 to enter samples into LIMS. The work was done manually, but it was done either in the laboratory or at the stock-management area where samples from the ordered products were taken. This was, however, problematic as the non-laborants did often not know how to use the system properly.

Analyzing samples or entering the results into LIMS varied widely depending on the configuration. All laboratories had old instruments which had to be operated manually, meaning the results were first entered on paper and then manually written into LIMS. All laboratories also had more modern instruments connected to a computer, however they did not support direct imports of results. Therefore the results were first exported into a file on a shared network drive, from which they were then imported into LIMS. In all laboratories except the one in company 4, there were also a varying amount of instruments which were directly connected to the LIMS system and the results transferred directly. In company 4 they wanted to review the results first before they were entered into the database and they had no real additional benefits from an automatic connection as they were heavily dependent on paperwork.

Approval of results was in all laboratories except company 2 a layered process where the results were informally first checked and approved by the laborant who ran the analysis herself. After this the results had to be approved again, this time officially, by another laborant (company 3), a laboratory administrator (company 4) or a chemist (company 1). The processes for approving results were twofold, first the person running the analysis checks the control samples (known samples that are used for testing the instrument).

If the control sample is within measurement limits and the trend is not alarming, then the samples are approved. There is, however, a second check considering whether the results are possible or not (in case of typographical errors, or accidents with one sample). The same things are checked by the person who does the official approval later as well (especially the trend would be considered more in detail by the person who did the acceptance). There seemed to be a big variance regarding the use of limits inside LIMS. Some laboratories used the limits for measurements inside LIMS (to indicate whether the result is within a realistic limit and to indicate if it is a possible result at all, so called outer and inner limits). Some laboratories had even the limits entered for some analysis methods but not for other. There were also some displeasure expressed by the fact that you could control certain things (how many visible decimals, for example) only through specific result entering windows (not the generic result/sample info/editing view which they preferred). Some calculations were also done by hand rather than inside LIMS. For this Excel sheets were used in at least company 1 for assistance.

Reporting was mostly done by the person in charge of officially approving samples. In company 1, this was the chemist and in company 3, the person who happened to be assigned to that post that day. In company 4, the reporting was slightly differed. After the approval of results, the report was forwarded to another body of the organization that was responsible for QA. There were, however, indications that the people who wanted to see the results checked them from LIMS, rather than waiting for an official report. In company 2 the reporting was done by the administrative laborant who did, however, not accept the results, as this was done by the analyzing laborants themselves. The method of reporting different widely. Company 1 had firstly an internal system where the results were sent and secondly they had to send reports via e-mail to external customers. Billing was bundled into this as well, with each procedure having a set cost. In company 2 the reporting was done via e-mail to external recipients, or to managers. The other people at the organization used a light weight LIMS to read the results. In company 3 there was first and foremost no reporting at all if the customer was internal and the results were acceptable. If the results failed, however, they would make a report via an inside QA system. The results were, however, sometimes automatically exported to another system that would use them. The external customers would receive e-mails with reports as well as use an Excel sheet to inform of the results in some cases. Only in company 1 and 3 was billing relevant, and only company 1 used the LIMS for it.

As a side note to approval and its' parent category – QA – it is worth mentioning that traceability of the results was important. Company 4 emphasized this heavily, but it was an issue in at least company 1 and 3 as well. It was important that it could be found out who had performed the analysis and who had approved the results. Also other considerations, such as date and time were important. This, however, done by paper in at

least companies 1 and 4. In companies 2 and 4 it was less pronounced, and relied on the LIMS. Therefore it is an important issue that needs to be kept in mind when designing a new LIMS.

Another important specialty are control samples. They assure that the instruments are working properly and do not require calibrations and are therefore an important part of quality assurance and the validity of the results. The handling of said samples varies though. Control samples were not marked as such in LIMS and they would have to be manually connected to batches of samples. In the LIMS in use there was a possibility to mark control samples separately, but it was not used in all companies. The control samples had their own identifiers and could be found through that. There was a wish to combine control samples to batches and samples, from where one could easily see trends and limits. Automated failing of related samples was also wished for, if the control is out-of-specification.

Another requirement that became apparent during the company visits was the need for a simple LIMS interface. This could be used for customers, both internal and external, to view results and reports. It could also be used by customers to register samples with. Company 2 already had something similar in use, and company 4 and 3 expressed interest in such a system.

Some other things to consider was the search functionality, which was seen as a bit too basic. In some cases a free text search was wished for (not only sample id). Another issue was the paper use in laboratories. In company 3 they made a push for removing the use of paper, which then requires a LIMS that supports their processes in all different matters. Especially when it comes to work management. In company 1, 2, and 4 there was a significant reliance on paper. Paper was used as official records in 1 and 4, as well as for work management in company 1 (same paper).

6.2 Flow model analysis

Flow models have a focus, meaning that they are drawn from the point of view of one particular person or other actor. In this case the flow models are made from the point of view of the LIMS itself, meaning that it is in the center of the model. First the the flow of all individual flow models relating to each company will be discussed and then the different flow models will be summarized. The flow models for the individual companies will not be included into this thesis. The flow model for company 1 can be found as an appendix under section C.1 at the end of this thesis and the summarized flow as an appendix under section C.2.

6.2.1 Company 1 flow model

In company 1 there are three actors next to the LIMS: Chemist, secretary, and laboratory assistant. To these three one could also count instruments or devices in the laboratory. The instruments in the laboratory either act directly on the LIMS (sending the results directly) or then the results are noted by the laboratory assistant. The samples always have to be prepared and entered into the instrument by the laboratory assistant. The laboratory assistants' interaction with LIMS is simply limited to entering results and potentially proofing the results. The laboratory assistants convey daily summaries to the chemist, so that the chemist knows what samples have been analyzed. This is done over Excel and paper. The laboratory assistants get their work handed to them by the secretary (and indirectly by the chemist who is repsonsible for prioritizing and organizing work, even though this is not shown in the model).

Chemists are the all-around people at the laboratory, who have a stake in everything. They approve samples in LIMS and they also approve batches (not supported by LIMS so it is done unofficially). They maintain registers in LIMS as well as review statistics and diagrams for proofing the quality of the analyses. They also have direct contact to customers and often receive analysis requests as well as do the reporting. They also direct the laboratory processes as well as register samples when required. Many of these tasks are the same as for the secretary and they therefore coordinate a lot and actually sit in the same room. The secretary, like the chemist, also register samples and receives analysis requests from customers. She is also the one in charge of receiving the samples when they appear at the laboratory as well as billing. She also coordinates with the chemists for laboratory processes and work management. Her interaction with LIMS is limited to maintaining customer registers, reporting, billing, and registering samples.

The customers have an indirect relation to LIMS. In the case of an internal customer, they can add the samples already themselves into the system while external customers have to send a request to the laboratory. Their interaction are with the chemists or the secretary, whom they contact for analysis. The reports are sent by the chemists (or secretary) to the customers. Interestingly enough, the points of failure in the flow model all relate to either problems with the instruments or lack of information (from the customers).

6.2.2 Company 2 flow model

Unlike company 1 with a total of seven actors (if instruments and customers are counted in), and customers split into external and internal, company 2 has up to twelve actors, depending on the definition of actors. The central figure currently in the interaction with LIMS and others are the laboratory administrators. The laboratory administrators are laborants with the additional tasks that correlate to the chemist in company 1. The

central task for the laboratory administrators are reporting and upkeep of the registers. They also do analysis like the laborants, but not as much. For reporting the laboratory administrators use up to four different channels. There is an external, light weight, LIMS that is used in the different factories by product managers, process engineers, and even factory chiefs. Additionally the process engineers use the web-based LIMS for entering results as some analysis are done outside the laboratory and for registering samples.

There is also an external QA system that is used for deviation reporting. So when a sample is out-of-specification or some other issues have happened, the laboratory administrators reports the deviation to the QA system, which is then checked by the relevant people in the factories. The QA system is also checked by the laboratory manager. The administrator laborant additionally sends statistics regarding control samples to the laboratory manager in Excel format and uses BusinessObjects for generating reports for internal use. Additionally to the vast amount of reporting, the admininistrator laborant is also in charge of control samples and actually is in charge of registering and preparing them. The work management is also done by the administrator laborant with the help of another external program.

Laboratory assistants have a rather wide role as well. They are ultimately responsible for their own work and accept the results on their own. They also register samples into LIMS when necessary as well as do reporting directly to external customers through Excel sheets. Interestingly enough, they also review their own results, as well as the results from the factories, in the web-based LIMS, rather than in the LIMS used by the laborants. The only other person having something to do with LIMS is the secretary, who handles billing. LIMS is however not used for the billing.

6.2.3 Company 3 flow model

Company 3 has a different organizational model than the two aforementioned ones. The organizational chart is flat, meaning that everyone does everything in the laboratory. There are some exceptions, with a limited number of people having administrative rights to the LIMS as well as there being a QA engineer who is responsible for assuring that the control sample values are inside the specification as well as for billing. At the same time this person is a system administrator and a laborant. The QA engineer bills the customers with the help of an external system.

Unlike in the other two companies, in company 3 the work is allocated according to work stations, not samples. The laborants spend around half a week, or a week, stationed at one station (one station can include up to three different instruments) and analyzes the samples that come through there. After the timeframe is over, the stations are rotated. It involves everyone doing approval of results and work scheduling at some point, as well

as registering samples and receiving analysis requests.

In a laborant position, the person interacting with LIMS has varying roles. In one role the laborant has to receive samples, prepare them as well as register them into the system. This means that next to doing this work, the laborant also does some simple analyzing of samples (a station that does not require too much effort). The other stations require full-time analyzing. An interesting point to make here, is that when checking the measurement limits, they do not rely on LIMS, but rather on papers where they calculate the limits and have them written. The laborants are also responsible for registering and reviewing control samples.

The laborants in the system administrator role have other tasks. They accept the results by first reviewing control samples manually again and by reviewing the results of the analysis. They are also in charge of reporting to external or internal customers in case of a measurement that is not within the limits set for the particular product as well as in charge of maintaining registers and managing work (which is done by a whiteboard). They also receive analysis requests.

Unlike at company 1, the internal customers in company 3 do not register the samples themselves. They send the analysis requests to the laboratory. Additionally, the reporting is done through Excel sheets (for internal customers) and e-mails with attached reports.

6.2.4 Company 4 flow model

Company 4 have few interaction points to the LIMS. There are laborants and then people working in the purchase department. The people working in the purchase department exclusively only register samples into the system, and are the recipients of the reports.

The laborants are separated into two groups. Regularl laborants and Quality Control (QC) laborants. The QC laborants have the same tasks as laborants, but they additionally have to approve every sample and manage work (which is done with Excel sheets). They also have to do some statistical reporting to the QA department as well as send the signed reports there. The process is done fully on paper, with LIMS used as an intermediate storage device from which the reports are printed. The results are fully analyzed on paper. They do not have any instruments that automatically import the results into LIMS, because they have to review everything personally. Because of these strict QA measures, the signing of the reports are done by hand and stored in paper format. The reports become available in a separate QA system for the purchase department for reading.

The regular laborants are doing regular laborant tasks. Preparing samples for analysis, analyzing the results and entering the results into LIMS. They are, however, more adamant about the quality of their work than in other companies, where the initial

approval by the laborants is not done as thoroughly as here.

6.2.5 Summarizing flow model

When considering the four companies and their organizational charts and the resulting flow models, it is quite clear that the roles are different when it comes to every organization. Therefore, no one can assume a certain split of the work done. That being said, there are some distinct roles that seem to be visible under all the different naming schemes of the people working in laboratories and the differing work descriptions. The function of LIMS is always to house samples and perform tasks on these samples. The customer's role is always to request for an analysis and ultimately receive the report thereof (as well as pay for the analysis). There are certain variations to this, where internal customers are able to register samples as well. This duality has until now been done through the LIMS interface or through other, more simple LIMS implementations that share the same database. One cannot assume that the external systems will always be in use or not in use, but there is clearly a possibility here (and it was also insinuated by customer 3 and 4) that there could be a website with a simplified UI of the LIMS where results could be read (would also ultimately save time on reporting) and where the customers could request analysis or register samples.

Another role that is prominent is that of the laborant. The laborant registers the samples (in some cases) and, most importantly, perform the analysis of the samples and handles the entering of results into LIMS. In the case of an automatic transfer of results, they still have to review the results for inconsistencies. There are a number of actions that could be performed automatically, not least the automatic rejection of the samples if the control is out-of-specification. The control sample is handled by the laborant as well.

A chemist has a managerial role in laboratories. They maintain registers, send reports to customers, accept the results as well as report to higher ups and manage the work in a laboratory. In some cases they are also responsible for registering samples and registering control samples, depending if the sample is in the system already or not. Moreover, the secretaries tend to handle things that have to do with billing, even though they can be completely exempted from the laboratory processes centering on LIMS, or have some of the responsibilities of a chemist. The communication to laborants is centered on work management or sample results.

6.3 Sequence model analysis

The sequence models in this study were done on four of the most prominent tasks undertaken in a laboratory regarding to LIMS and samples. These are the registration

process of a sample, the analysis of a sample, the approval of a sample, and the reporting of the results. This is the main purpose of a laboratory, to analyze samples and provide the results to the person who needs them. Consequently, there are four models per company (example from company 1 found in the appendices under section D.1) as well as four summarized models that attempt to find some common patterns in the tasks in the different laboratories. The models could all each be analyzed, but that would perhaps not be purposeful for the thesis. First there will be a quick word regarding the different sequences at each company, followed by an in depth analysis of the summarized sequences (can be found in appendices under section D.2). The summarizing of the models allows one to analyze the different sequences and spot differences or similarities in the processes. It also is a first step towards an implementation that satisfies all the needs.

6.3.1 Company 1 sequence models

In company 1, the registration of samples is simple. It consists of a number of small sub-steps. The process starts with an analysis request from a customer (internal or external). In the rare case that the customer is not in the system, he would then be entered into the system. The analysis request is then entered into the billing system. Once the samples physically arrive at the laboratory, the samples are registered into LIMS (in the case of an external customer) or a quick check is done to make sure they are there already (in case of an internal customer). The barcode labels are then printed together with a results form. The label is attached to the sample(s) and the form is added to the pile of pending samples to analyze. If it is an analysis with a high priority, it is put into a pink folder on top of the pile. This is performed by the secretary and/or the chemist.

Once the laboratory assistant picks a sample to analyze, she proceeds to check what analysis are scheduled for this sample. She then prepares the samples for the analysis to come and enters them into the instrument which performs the analysis (or runs it manually herself). Depending on the instrument, she now has to either manually enter the results into a notebook or then validate the results on paper or on the computer once the results are in LIMS. If the control sample fails, she might have to rerun the analysis. The other two instrument options (automatic import of results into LIMS or manual import) work similarly with the checks and validation of the results, with the exception of the number of steps needed in between. Once all results are entered into LIMS from all the analysis, the sample is set to the ready status and the form is added to the pile of finished analysis.

When the chemist checks the Excel list of finished analyses for the day, she can proceed to validate the results. The control sample is checked for the result and checked if it is according to the specification. The trend of the control is also checked. If this is the

case, then the results are checked abnormalities as well as the whole batch is compared to earlier values. The results are then accepted. In the case of abnormalities, a judgment call has to be made regarding whether the results are due to a measuring fault or because the samples are or different quality than earlier ones. If there seems to have been problems with the analysis or instrument, it is set to be calibrated and the analysis is then run again.

Once the results from a batch is done, the reporting is done according to two different processes. If the customer was internal, the results are simply exported to the shared QA system along with comments on the results. Also billing information is sent there. If the customer was external, the statements are added as well, but the results are sent as an e-mail. The bill is either sent by e-mail or through mail (the results can also be sent by mail).

6.3.2 Company 2 sequence models

In the case of company 2, there are two ways samples can be registered. If it is a regular sample from the stock, then the sample is registered from outside the laboratory into the system. The samples are then sent to the laboratory for analysis along with an analysis request. The sample is then simply added to the work queue. If it is an external sample, then it arrives at the laboratory where it is registered. In some cases the analysis is first run and the sample is registered at the time the results are entered into LIMS.

When it comes to analysis, company 2 does not differ much from company 1. The analysis proceeds exactly the same way up until the results are entered into LIMS. After this the results are approved as well. There is no secondary review. Once the sample is approved the transfer of results from LIMS to the external light-weight LIMs is affirmed. The reporting is also straightforward as the results are either read directly from the light–weight LIMS by the internal customers or then the results are exported into a word template, where comments are added before the report is sent via e-mail or mail.

6.3.3 Company 3 sequence models

At company 3, the samples are registered into LIMS once they have arrived at the laboratory. The analysis request arrive with the samples or earlier via e-mail. The samples are also given an id before they are entered into LIMS (normally the id is given by LIMS automatically). Company 3 has a roll with pre-generated id sequences which are attached to the samples and the id is entered into LIMS. If the samples are urgent, then they are added to the top of the work list.

The analysis process is identical with company 1, with the exception of the sample moving

places, not the analyzer. The approval sequence is also identical to company 1. The control samples, the trend of the control samples, the trend of the product as well as the results of the samples are all checked and validated like in company 1. If everything seems alright the batches are approved. The interesting part at company 3 has to do with the reporting. There are essentially three different ways of reporting, depending on the customer that is in question. If the customer is internal, then the approver does no reporting at all. If the results indicate a quality problem in the product, then a reporting is printed and commented on and this is then filed as an incident report. If the customer is local and has access to a shared drive, then the results are entered into shared Excel with comments. In the case of a completely external customer, then the reporting and billing is done normally, by e-mail or mail.

6.3.4 Company 4 sequence models

Like at company 2, company 4 has two different ways of getting samples entered into the system. One is internally by someone else in the company (through the same LIMS, not any simplified versions) and the second way is by registering them into LIMS as they arrive at the laboratory. Once they are in LIMS and the samples are at the laboratory, then they are added to the work lists (which are entered into the analyzing instruments themselves when possible).

The analysis is similar to all other companies, the exception can be found at the end, where the results are accepted immediately once the laboratory assistant has validated them (the approve functionality in LIMS is only used to indicate that analysis is finished). After the samples are approved they are printed out on paper.

The results are now approved officially by the laboratory assistant who performed the analysis. Now the results are validated again by a QC laborant who also performs the normal validations for the control samples. If everything is in order, the QC laborant approves the sample as well. If the results are in order, the results are sent forward to QA. In the case of a problem with the results (but the instruments are functioning correctly), a deviation report is sent to QA. At QA they also do some validations for the results and archive the paper if no problems are found. Else they will make their own deviation report into the QA system.

6.3.5 Summarized sequence models

While registering new samples, there are two methods that companies use. The biggest difference is regarding if the customer has LIMS access or not. If the customer has LIMS access, it is likely that they are entering the sample, with its required information. If they

are the ones registering the samples, there could be a need for a simplified interface or and education into using it. The registration of samples from the customer's side is the same as when it is registered in the laboratory. If it is registered in a laboratory, the sample has to first arrive, before it will be entered into the system. If the laboratory in question is a service laboratory, there might be a need for updating the customer information before the sample is registered. QA laboratories have a process (laboratory 2 and 4) where the sample is registered by the customer. In service laboratories, the choice of analysis might have to be editable, as it might differ between customers.

The analysis of the samples followed the same pattern in every laboratory. It is basically the only way to analyze a sample, even though there were some nuances. In some cases one sample was analyzed by one person from start to finish, in other cases it was station specific, meaning one person would only run one analysis. In all laboratories there were manual, digital systems as well as automated instruments. The reviewing of control sample values and assuring the results were correct, was done in all laboratories as well. The manner of this did, however, differ widely. In some laboratories, all calculations of the results were done in Excel or by hand (for example company 4 and 2, in others inside LIMS automatically (company 1 and 2). In some laboratories the control samples were not really differentiated from normal samples, while in other they had their own id tag. This connection between samples or batches and control samples seems like it could be made more explicit in order to streamline a lot of work. The same is true for the calculations done, even though they are supported in LIMS but not used currently.

The approval sequence (except in company 2) was always identical. The person doing the approval, would essentially walk through the similar steps as a laborant once the analysis has been done to make sure the results are valid. The main difference lies with checking the product trend, the results of earlier batches and the trend of the control samples as well. The approval might be done purely on the basis of the control sample, with the actual results playing a smaller part (except for the trend) in the end for approving the samples. The acceptability of the results are done through reporting.

The reporting is fairly simple in all cases. Once the results are approved the customer (internal or external) wants to see them. If they do not, then nothing has to be done after the results are approved. If the recipient has access to LIMS or the database where the results are stored through other means, then they can go there to review the results (possibly by first being notified that the results are there). The other way is to create a report, often with a comment attached and a signature. The billing can be done and sent at the same time with the report, or separately. The billing could be attached to the analysis (through analysis pricing) or could be calculated through other means. If it has to do with the analysis, then the billing could easily be attached to LIMS. It should be noted that there is also a clear requirement for signing, meaning digital signatures.

Currently a lot of the signing is done on paper, with only a few things happening in LIMS. There should at least be a signature required when the analysis is finished, when it is being accepted and at the time of commenting and reporting.

6.4 Cultural model analysis

In this chapter the cultural models of each company will be discussed. The models represent the interaction and relation between the different people in the organizations, as well as the individual wishes of them. Company 3's cultural model can be found in the appendices under section E.

6.4.1 Company 1 cultural model

In company 1, the work culture is much centered on the chemist. The chemist is the central person for communication for the laboratory assistants, the laboratory managers, secretary as well as the customers. She is responsible for the processes and therefore attempts to optimize them, without sacrificing quality. The chemist feels, however, that the amount of work available limits them from renewing themselves and changing processes. The laboratory manager communicate gives the strategic goals to the chemists, who then have to fulfill them. The laboratory manager is in charge of making sure the laboratory is profitable and thinks changes in the laboratory should have proven long-term benefits to profitability. The communication towards laboratory assistants from a chemist is centered on work lists and from laboratory assistants to chemists on providing results. The secretary coordinates customer related things with the chemist. She has to do many different tasks, many differing from a traditionall secretary's tasks. Both the internal and external customers want to have fast analysis done at a low cost. A sort of "it needs to be done yesterday" mentality is used towards the laboratory. The external customers, do however prefer the cheaper analysis version where they are not pushed to the top of the queue.

The culture in company 1 seemed slightly strained. The atmosphere among the workers was good, but there was a slight sense of chaos. The processes were not as efficient as they could be and there was a genuine will to change them. However, the pressure from higher up to keep up with the work was working against the needs for reform. There is clearly a certain need for a newer system which would help them with organizing work and improving the throughput of samples with the help of built-in algorithms.

6.4.2 Company 2 cultural model

In company 2 the work is also centered on the chemist (laboratory manager). The biggest difference to company 1 being that the administrator laborant is in charge of most day-to-day tasks that the chemist at company 1 was in charge of. The chemist manages the work processes and oversees the quality at the laboratory. The attitude is however one where the easiest way to do things is adopted. The type of overhead that is present at most laboratories cannot be seen here. The chemist communicates billing information to the secretary when needed, communicates the work practices to the laborants and administrator laborants. They also convey some quality related results to factory chiefs, product managers and process engineers. The administrator laborant is focused on quality and making sure the processes are implemented as well as the quality practices. She is also focused on making sure registers are up to date, but finds it time consuming to do reporting and the analysis required for it. The administrator laborant has a close cooperation with the laborants, who try to avoid making errors. The laborants also find that working without LIMS is often faster. The people at the factories (process engineers etc.) are interested in seeing the results from the analysis and wants them as soon as possible. They do, however, seldom directly communicate with laboratory personnel.

The culture at the second company seemed relaxed. The lack of a real authority figure became quite clear, as the laborants were ultimately responsible for their own work. It is questionable if they work efficiently or accurately under the current circumstances.

6.4.3 Company 3 cultural model

In company 3 laboratory administrators are in a central role. As mentioned earlier, the system administrator engineers are rotated weekly which makes the role split slightly arbitrary. There are a couple of senior engineers who are ultimately responsible for the enforcing the processes at the laboratory though, and the cultural model here is made to assume they are working as laboratory administrators at the current time to simplify the role. Ultimately though, it is a flat and democratic organization.

The laboratory admininistrators are central in this cultural model. They allocate the resources and are currently suffering from a lack of personnel compared to their workload. Therefore there is a larger restructuring going where they are trying to find ways to make the laboratory more efficient. In order to keep motivation up and to maintain their efficiency (mentioned in the flow model) they rotate stations at least weekly. The quality of the work is adamant, and therefore there is a great focus on the quality aspects of the processes as well. The cooperation between the laborants and the administrator laborants is close. The customers need, like in the other cases, their results as soon as possible at a reasonable price. The laboratory chief and the corporation itself, felt

that the laboratory was not working efficiently enough, so the incentive to remodel the organizational structure came from there.

The eventual situation at the laboratory is difficult to assess because of the restructuring. The democratic nature of the laboratory makes them have a good team spirit and they seem to work efficiently (perhaps partly because of the station-centered analysis model?). The current lack of resources is attempted to be fixed by having fewer batches arrive at the laboratory, but considerably larger, at one time. This would mean hundreds of new samples would arrive perhaps once a month. It is not clear whether this puts more or less stress on the organization, but it is an attempt to streamline the processes.

6.4.4 Company 4 cultural model

Like in the aforementioned laboratories, the culture in company 3 is similar in the sense that there is a central, coordinating entity that receives orders from higher ups and makes the day-to-day adjustments to make company strategy reality. In this case it is the QC laborants. They have to cooperate and coordinate with entities outside the laboratory environment and assure that the quality of the work in the laboratory is good. They have conflicting parties they have to coordinate with though. The purchase department want fast results, but the results do not ultimately come to them from the laboratory. It puts some time pressure on the laboratory. They also hate using LIMS, which makes the relationship slightly strained. The laborants themselves are the one group who like using LIMS. They think it makes their work a lot more efficient and would prefer to use as much LIMS as possible, but are forced to use papers because of existing processes. The quality control engineers are also positive to the use of LIMS, but they also understand and appreciate the overhead the papers use give them. The QA department are enforcing the processes on the laboratory and want to make sure the processes coincide with the industry standards.

The strains and preferences of the different parties here could clearly be improved by a LIMS that fits their needs better. A digital signature system that is present in the modern LIMS would seem appropriate for the standard needs as well as a simplified interface towards the purchase department. Additionally, they could have access to the results earlier.

6.5 Physical model analysis

In this sub chapter the different types of physical spaces in laboratories will be presented, while attempting to draw some conclusions and parallels between them. The physical space of a laboratory cannot, however, be changed. The undertaking is too big with sinks

and rooms dedicated for dangerous chemicals or requirements for sterility. An example of the physical models (in this case of company 4) can be found in the appendices under section F.

6.5.1 Company 1 physical model

At company 1 the layout is straightforward. The laboratory space is rather small, so there is little space to spare. The three chemists share a room with the secretary where they do most of their work. There are also printers for both labels for the samples as well as for reports and other papers available there. The laboratory space is made up out of one big room, and three small rooms. In the big space there are no specific order of things. Analysis with dangerous chemicals as well as with automatic instruments are done here. The same applies to the smaller rooms, with the exception that they are dedicated to one or two types of analysis. Each room has a computer connected to LIMS, and in some cases each instrument has one, where it is relevant. The big room has a computer per work section that is connected to LIMS. Some instruments also have a computer here. The whiteboard for work management was in the middle of the laboratory. Sample preparation was done in the middle of the laboratory.

6.5.2 Company 2 physical model

At company 2 the layout is also straightforward. There is a big laboratory space and many small office spaces. The office spaces are used for work on computers (e.g. reports), while the laboratory is mostly used for analysis. In the laboratory there is only a limited number of computers, in total three terminals that can be used for entering results into LIMS. The laboratory administrators have their own office where they spend a big part of their day reporting and managing work. The space itself is big, but comparably, the laboratory does only take up a third, or less, of it, where at company 1 the laboratory space took up over three quarters of the space. Sample preparation was done in a corner in the laboratory.

6.5.3 Company 3 physical model

At company 3 the layout is also centered on the laboratory. There is more than enough space, as some smaller laboratory rooms are standing unused. Most of the analysis are done in a big open space where there is a number of computers hooked to LIMS. They did, however, do a lot of their result entering in the office room, as they had their own terminal there. The office room was rather big, and filled with workstations. It was in constant used by the person who happened to be on administrator duty as well as

laborants entering and analyzing results. The whiteboards for work management were in the hallway between the office and the big laboratory. Sample preparation was done in a separate room.

6.5.4 Company 4 physical model

At company 4 the layout was different. Where in the other companies the building was essentially dedicated to laboratory work, the building at company 4 was also an office building. The entrance to the office lead through a number of small offices and meeting rooms, followed by a large kitchen. At the end of a long hallway was the laboratory. The laboratory was split into three. One big open laboratory space where the analysis was done and the acceptance. There was a number of terminals there for LIMS access, one for each work station. The two other spaces were closed, sterile environments where only analysis were made. The QC laborants would, however, do a part of their job in their office, which was in the office part of the laboratory. There they would do things not directly related to analyzing samples (even accepting the samples) and reporting, as well as QA related tasks. The QA department was situated in the office part as well.

6.6 Artefact model analysis

In this chapter the different artefacts used in each company will be presented. The goal is to get a general picture of what sort of tools they use outside of LIMS and to then ultimately consider if some of these could be integrated into LIMS.

6.6.1 Company 1 artefacts

The artefacts seen in company 1 are the following:

- Paper for listing samples and results
- Paper with list of samples and their analysis process
- Pink folders for prioritizing
- Whiteboard for listing waiting jobs
- Notebooks/papers for temporarily entering results
- Machine for reading bar codes
- Excel forms for listing finished analysis

- Excel forms for calculations
- Analysis requests

As can be seen from the list, the artefacts are all centered on work management. The pink folders, the whiteboard, list of samples with their processes, Excel form for listing the finished analysis, as well as the paper form of the results all indicate a lack of support for workflow management in LIMS. Also better calculation alternatives for the samples should be considered, so that they do not have to be run in Excel.

6.6.2 Company 2 artefacts

The artefacts seen in company 2 are the following:

- Table for info of what samples have been transferred to other LIMS.
- A light-weight LIMS for viewing results and entering results
- Excel forms for single samples for research, because calculation in LIMS is perceived difficult
- Excel to send results somewhere and add comments
- QA system to generate deviation reports
- Excel form for summarizing info regarding control samples. Excel database queries for retrieving the information. Comments important here. Different views to view control samples, one for each analysis.
- Excel forms for entering certain sample info (that is not supported in LIMS).
- Notebooks/papers for temporarily entering results
- Machine for reading bar codes

The artefacts in company 2 are, unlike in company 1, centered on reporting. There is one artefact that is also centered on workflow management, but mostly because there are two different LIMS in use and it provides an overview of that. The reporting functions in LIMS have clearly either not taken off or have not supported the needs of the company. The commenting of results is something that was also mentioned separately at company 1, so it should be something to keep an eye on. Also getting information regarding control samples through a custom Excel script insinuates that the control sample functionality in LIMS is not seen as easy to use or descriptive enough.

6.6.3 Company 3 artefacts

The artefacts seen in company 3 are the following:

- Paper for seeing work lists and samples that are run. Doesn't take priority into account (supposed ready date).
- 4 Whiteboards:
  - Info regarding where people are/general tasks and what has to be done (control tests etc.)
  - People are assigned tasks that they are responsible for over the day/week.
  - Some general info
  - More info (who works where, who closes, holidays, safety stuff)
- Excel for showing status of "locally produced" samples, which can be seen by customers.
- Manually create an Excel where the sample result is added to the Excel with a second sample to see if two samples are close, when a sample fails the sensory test
- Word template for different reports
- Analysis requests
- Notebooks/papers for temporarily entering results

The artefacts are not focused on one particular area here. There are artefacts relating to workflow management and reporting. As a novelty, there are artefacts relating to comparing two samples with each other. It is also worth noting that there is already a shared resource with external customers, which would indicate a need for a light-weight system aimed towards customers. The difficulty of the reporting system is more pronounced. Additionally, it's worth noting that it is now the second time the analysis requests have arrive by e-mail or by paper and an external system could potentially also take care of this.

6.6.4 Company 4 artefacts

The artefacts seen in company 4 are the following:

- Papers as official documentation and acceptance. The papers are sent forward.

- Work lists in Excel to manage work lists (prioritization, removing samples, reordering etc.)
- Excel files as a mid-step for importing results. Need to be able to choose what results go into LIMS and to add some extra stuff before it goes in as well.
- Notebooks/papers for temporarily entering results.

The strict QA process and the paper-centered approach has been discussed earlier, but it does seem to be the major part of the artefacts. The work is managed in Excel, which indicates some perceived difficulties with the work list capabilities of System 2 as well. The Excel files for editing data before it is imported into LIMS seems like a rather peculiar need. Could need some further analysis regarding the need of this particular customer, but it not something that can be considered in a new LIMS, but rather in the configuration for the customer.

7 Results

In this chapter the ideas and results based on the analysis in the previous chapter will be presented. At first the the ideas that came up in the affinity diagram will be introduced, followed by an explaining of the consolidated models. Finally the storyboards will be presented and discussed.

7.1 Affinity diagram

An affinity diagram was created in order to gather some of the ideas that came together during the initial analysis of the gathered material and the modeling of the work in the companies. The goal is to get a general view of the issues that currently exists as well as the improvements that can be made to LIMS and the general workflow of the companies using it. The affinity diagram can be found in the appendices.

IT should be noted that the contents of the Affinity diagram will only be presented briefly. The identified categories in the diagram were:

- Sample registration
- Entering results
- Control samples
- Sample states / approval

- Work control
- Batch control
- Reporting
- Registers
- UI
- Statistics

The main improvements brought up in this affinity diagram are regarding work control, the UI paradigms, and a built-in, simplified view towards customers and other parts of the organization who are not familiar with LIMS. It would be a simple view, with two functions: Registering samples and viewing results. This would remove the paper trail completely (even though it is not mandatory) for many laboratories as well as remove the need for sending e-mails to customers. This could potentially save a considerable amount of time per day. The challenge is presenting the registration process and the result view in a way that the customer can understand.

The work-control is in some LIMS non-existent, and in other LIMS there are some possibilities regarding it, but it seems to be only in moderate use. There should be a view where the user can see the work that is scheduled for her. The samples could therefore be assigned to different people, or perhaps parts of an analysis. So if a sample is in the work queue, then it would be possible for both laboratories where one person analyses one whole sample and in laboratories that have stations, to schedule the work. The systems which are to be replaced by this one, are sample centered, and it is challenging to get a view of more than one sample at the time (can only be achieved an extra search functionality). Therefore many summaries and lists of samples are kept separately. The platform, on which the new system is to be built, is on the other hand list-centered. This means all actions are done through a list interface, to which you always have to go back to and the results are hidden a couple of hierarchies in. They both seem rather inefficient on their own and thefore a mixture of both approaches could be used. The list view for partially navigating the samples (get a quick overview and selecting) and then a sample-centered view as the following view, where it is possible to cycle to the next sample on the previous list page by clicking just one button.

Another improvement would be more automated processes. The functionality of the limits should be automated better (in some cases the limits are not static, but they depend on the control sample result). Another process to automate would be the connection between control samples and normal samples. If a control sample fails, then the whole batch should fail automatically. Currently there are many manual processes involved. When

approving batches and when reporting the results, the statistics play a central role. The question is how to bundle in the statistic into the program. Reading the statistics from a different view than the sample-centered one would be convenient, but it has the potential to complicate the UI considerably. Another view would provide a cleaner interface, but the connection to the given sample and the approval thereof, would then be compromised. It is therefore better to have the functionality available on the sample-centered view, but the controls somehow slightly hidden.

The benefits of the proposed changes and improvements will become clearer in the consolidated sequence models and the storyboards following them. There is a number of improvement and features suggested, some of them vital (like a better audit trail and digital signatures) which will be less central here, as they are already supported in the platform on which the new system is built.

7.2 Consolidated models

In this chapter improved versions of the sequence models will be discussed. The four different models (registration, analysis, acceptance, and reporting) are all improved based on the ideas presented in the affinity diagram as well as by analyzing the original sequence models for improvements. The models can be found in the appendices under section H.

The registration process of samples is in most companies done by the requester or by the laboratory personnel. The situations where the samples are readily registered by the requester, the process seemed considerably simpler. The sample is registered before it arrives at the laboratory (which are the users of LIMS) and can just be added to the work queue. The analysis request differs from laboratory to laboratory, but it requires some effort from the chemists in the laboratory. By outsourcing the registration to the customers, it will make the process more streamlined for the laboratory. The registration of samples would happen through a light-weight LIMS interface that is opened up to the customers. In order to use it, the customer needs to get login credentials from the laboratory. These will have to be setup once, in other cases the communication over e-mail and phone can be reduced. The process can also be traditional like before, where the laboratory registers the samples, but the option for a more efficient registration process should be there.

The analysis is identical to the sequence models mentioned earlier, with one exception. The exception regards the use of LIMS in all cases of analyzing the results. The customers had often the situation where it was perceived easier to do calculation on paper or where it was not possible to do the calculations in LIMS. In order to assure that the LIMS is the most efficient way of checking results, it should be expected that LIMS should support a wider range of possibilities for calculating the results. It should also be expected that if

the control sample fails, then the related batches also fail. The failure of a control sample can be related to its immediate value (out-of-specification) or to the trend of the control. Especially the trend has to currently be checked manually, but it is also something that could be implemented programmatically. Another consideration regards the fact that the limits are in some cases "floating". They depend on the value of the control sample. E.g. if the expected value of the control sample is 0 and it has the value 1. The upper limit for the samples connected to this particular control sample is normally 5, but in this case it will be 6. This could also be automatically implemented into LIMS.

The approval sequence is difficult to improve. The chemists tend to review the control sample values and the trend of them. This is essentially rendered unnecessary because of the automation implemented into the analysis sequence. There will probably be a certain need for it for QA reasons, but the work relating to it is reduced and it will be more of a confirmation of the results. The trend of the samples and batches as well as products (historically) still needs to be analyzed by the chemists in order to comment on or give a statement on the results. This is something that would require considerable configuration for each customer, and is as such not a feasible option (installation time should not exceed one month). Additionally, the system could inform the chemist that there are samples to approve through a built-in notification system.

Reporting is made easy by the use of an external system. The light-weight LIMS can be used by the customers to view the results. The question is whether the system should show the current status of the samples and the results, or if the results should be transferred to the new system by chemists after comments are given. This could be potentially configurable, as there seems to be need for both (statements are more relevant in service laboratories). Additionally there could be a notification regarding the results. This notification could be through a built-in notification system, or through e-mail. The statements would therefore also be saved in the system, and not only on the reports (which is the case currently).

7.3 Storyboards

The storyboards in this thesis were created based on the consolidated models as well as based on the ideas expressed in the affinity diagram. It is worth reminding, that the storyboards in this case shows the whole process of the registration, analysis, approval, or reporting process. In the appendices under section I one can find the registration storyboard. The storyboards will not be discussed in great detail as the features seen there have been explained and suggested already in this chapter and the evaluation of using storyboards in this software project will be done in the next chapter. Some interesting aspects of the UI or the process itself that have not been brought to the forefront earlier

in this chapter will be discussed here.

The registration sequence starts from when a customer needs to have an analysis done. In this case "Brewer Joe" who needs to have his beers analyzed and approved before they can be sold. Brewer Joe contacts the laboratory responsible for these types of analyses and asks what he has to do, what it will cost and the time frame it takes to complete his request. The chemist receiving the call will then provide him with the information as well as get some basic contact information. Once this is settled the chemist will send a login to an external view of the LIMS to the customer, where he can log in and send an analysis request. The process of registering the samples or making an analysis request, can be made in a wizard mode where the information the chemist would normally ask on the phone can be chosen (how many samples/what for is the analysis done/urgency). These options would reflect certain values in LIMS, but in the language of the customer. There could finally be instructions on how to send the samples and the address they should be sent to. After registering the samples (making an analysis request) Brewer Joe sends the bottles to the laboratory with some basic information regarding them attached (sample ids, product name, and/or company name). Once the samples arrive in the laboratory the receiving chemist only needs to change the status of the sample and attach the official labels on them. Another option could be that a sample is sent to the laboratory and the chemist registers them. This process requires only filling in a sample view with information, like now. As much as possible regarding the information could be filled automatically. The sample is originally in a "Pending" status, meaning it is still not in the laboratory. Once it arrives the status will change to "Arrived" or maybe directly into "queued" once it has been assigned to the laborant. The samples can be assigned directly from the list view.

A key point regarding the analysis process is the use of control samples. It is important to couple control samples to samples and batches in order to differentiate between the two and in order to add some automation. Firstly, LIMS should be the primary tool for laboratory users to analyze the results, therefore automatic failing of control samples if the trend of the control for a specific instrument is out-of-specification or if the values do not fall within the limits is something that would be useful. Additionally LIMS should be able to do calculation based on the results from instruments in order to give the LIMS the real results that we are looking for. The level of automation here depends purely if the results are entered manually or imported automatically from an instrument. Automation in the instrument connection allows a higher automation inside LIMS, while manual entering of results is more tightly couple to the laborant. The result limits could also be floating depending on the control sample results. The sample could also automatically change status, but laboratory processes do require that at some point the laborant authenticates herself. Therefore when changing the status of the sample to "Finished" would seem like a

good opportunity. Another time to authenticate would be before editing/entering results and before they can be imported into the system. The actual process starts with the laborant picking up the sample and preparing it for analysis. This is then followed by entering it into the instrument and waiting for the analysis to finish. Now, if it is an old instrument without connectivity, then the results would have had to be entered on paper throughout the analysis and then now entered into LIMS. LIMS would then give errors and warnings regarding the results based upon which the chemist can approve them. The second option is that the results are automatically entered into LIMS based on the results. If the control fails, then the results should obviously not be entered.

Using an internal notification system, the chemist could receive a notification as soon as a sample or batch has reached the "Finished" status. This notification could also be sent via e-mail with a link to the samples or batch. Reviewing the control samples should be simple through viewing the results of the batches or samples. This sequence is the only one that can be assumed to always be the same. The different approaches do not affect the functionality or workflow. An important detail in making the workflow as efficient as possible is to easily have access to the control samples once you find the relevant samples. The samples in a ready state are also easily found through the navigation.

Reporting is also a split task, like analysis and registering. There is the option for the customer to see the results online through the light-weight LIMS that was mentioned earlier. This option requires little to no communication to the customer from the laboratory. The comments on the results would have to be made at first though, and the results potentially changed to a new status that would make them show up for the customer (it is not necessary for the customer to see the intermediate and possibly false results). The important detail here is displaying the results in such a manner that the customer also understands them. The comments are added to the report, but here there should be the possibility to comment in LIMS as well. The second option is for the chemist to send the reports herself. This can be done through templates and e-mail (or by paper). If the comments are generated in LIMS before the report is generated, then it takes care of some of the issues that has been ailing current LIMS users. Billing would be separate from reporting, even though it could be done in conjunction with the e-mail/paper reporting.

Optimally the storyboards would be without many functionalities. This means one way to register samples, one way to approve samples, and one way for reporting. But the realities are different, especially regarding analysis. Until all instruments in laboratories are replaces with new ones, manual result entering has to be in focus as well. Registration could easily be done without customer involvement and the results could be sent via mail. However, as one company had an external light-weight LIMS already in for this purpose and the rest of the laboratories either expressed interest in one (on their own initiative) or

had a clear need of a simplified interface to the outside, it is clear that such a functionality cannot be ignored.

8 Conclusions

This thesis attempts to explore the usefulness and validity of two things. First is the usefulness of UCD when creating a new LIMS and the second is the validity of using storyboards for depicting workflows in LIMS development. The results of these studies are also important practically, as they will be used for creating a new system. It should be noted that a new LIMS is meant to refer to a completely new LIMS and not only a configuration. The results obtained in this thesis can be seen as valid as Holtzblatt and Beyer (1998) suggest. They point out that despite having different end-users and different cultures and processes available for a user study and even though the companies seem different at first glance, there will always be something in common that can be used to create a system that provides a framework for all the nuances on top of this baseline. In the case of laboratories, it was reaffirmed that it is as Laukkanen (2007) pointed out, that there are a number of things about laboratories that always hold true. These are:

1. Samples are delivered to the laboratory (and not taken in it).
2. The results of the analysis are to be delivered outside the laboratory.
3. The analysis requester wants the results as soon as possible.
4. Info regarding similar samples is similar.
5. The samples are tracked through the laboratory.
6. Statistics regarding sample throughput and other related things are used for resource allocation, budgeting, and billing.

The sixth point was not emphasized in this thesis as it was not central to the four principal sequences that were in focus. Generally this type of design work is done in groups and the contextual inquiries in groups of two. This was mostly done as a single person project, with some help during half the company visits and some feedback during the analysis process. This restricts the validity of the results. It has also become clear, that some details regarding certain processes are still lacking (for example calculating throughput), but are not relevant for this thesis.

Other encouraging results were the fact that these results and existing workflow depictions are compatible (both from academic and professional sources). More details about these

workflow depictions can be seen in chapter 2.1.1. This study has also confirmed the importance of different parts of the LIMS for users, as suggested by the World survey of LIMS users by Strategic Directions International (2007; c.f. Skobelev et al., 2010):

- input of data and results
- enrollment of samples (registering samples)
- tracking samples
- report generation
- simplicity of use and training
- security of applications
- reviewing of results and their verification (validation or approval)
- customization of reports
- flexibility and adaptability
- conformity to normative documents

As can be seen in this list, the four targeted processes of analysis, registration, approval, and reporting are mentioned. Most of these items are, however, requirements and "simplicity of use and training" is what this thesis aims to address.

Regarding the results from the analysis, the laboratory processes are mostly heavily influenced by outside requirements or internal requirements and then optimized within those limits. On first glance LIMS does not seem to limit productivity, but rather enable it. There are, however, some issues regarding the usage of LIMS that hinders work. In normal use, there is only the fact that one sometimes has to navigate to a specific view to enter results. More problems are apparent when a non-optimal sequence occurs. For example the need to edit a sample, or the sample not being in the correct state. A surprising amount of requirements were also found in this user study. There were some lacking functionality, that had been in certain cases already implemented, but it would seem that the customers were not aware of the possibility or then they had not found the functionality. This seems to be a failure of marketing the features of the LIMS as well as a problem in the LIMS itself. The LIMS should offer functionality to the user at appropriate times, the user should not have to look for it. There were also some behavior noticed in some of the end users that hinted at adapting LIMS to their earlier working habits, rather than the other way around. The question remains whether the new system allows for many different working habits, or if it could prove to mold the users into using it in one, proven, effective way.

8.1 UCD evaluation

Anderson et al. (2001) pointed out that the human factors play an important role in software development, the human factors of both the customers and the developers themselves. UCD is the method of choice for them to address this issue and it would seem logical that it is also the way to move forward for Software Point. The LIMS industry, as noted earlier, is filled with process thinking from software development managers and the laboratory managers. But the people using the systems and the people developing them are rarely taken into account. As UCD has a agile emphasis (iterative development and design as well as involving as many stakeholders as possible in all stages of development) it has the potential to address both these problems.

The customers that were visited during the study seemed all genuinely interested in being a part of the study and helping to improve the existing systems. The experience was that they had a chance to express their wishes and that we, as a company, took genuine interest in their work and how Software Point could support it. It was especially praised by the customers in Sweden. They felt that they had the opportunity to express their wishes and needs as well as that Software Point, through observations were trying to find the optimal solution for them. It is essentially a great marketing tool, as Holtzblatt and Beyer (1998) have suggested.

Another aspect of UCD is that it fits well together with the agile practices that are becoming more common at Software Point. UCD can support these practices by improve the focus on users, which a part of the agile focus. There are other similarities between agile and UCD, for example iterative design and a focus on involving the whole team in the design and development. However, this is also where the main difference becomes apparent. UCD requires an understanding of the user before the iterative design part can begin, while agile attempts to start developing as early as possible. The amount of documentation is also a differentiating factor. (Chamberlain et al., 2006)

As for LIMS development, there are currently no related work regarding the feasibility of using UCD in LIMS configuration. The use of UCD in implementing a configuration of an ERP has already been proven by Vilpola. The assumption is, that in order to apply this approach to the development of a new system, the focus has to be on more than only one company (like it is in implementing the configurations). Having visits to several companies becomes therefore important as well as the accumulated experience from developers and sales personnel (who have often earlier worked in laboratories) becomes a useful additional source of information. Based on these premises the assumption can be made that the product will support the general structure that is there in every laboratory, as proposed by Holtzblatt and Beyer (1998).

8.2 Storyboard evaluation

Storyboards, are according to Newman and Landay (2000) mostly suitable for communicating within the developing organization and not towards customers. This is disputed by Holtzblatt and Beyer (1998), who point out that the general workflow found out during the design process and then presented in the form of a scenario, can also be a useful marketing tool. The general processes are also important to depict in a simple way, as it shows that Software Point understand the laboratory processes and have them well defined, and have therefore created a product which in turns supports it as well.

During the user research and at the start of the analysis of the results, the findings were communicated to others involved in the project. There was a significant interest in the findings, but they had to be expressed quickly in a summaritative manner. Once the data had been analyzed and the report created with the different models depicted in this thesis, it became apparent that it is difficult to communicate the findings onwards. The amount of information is rather overwhelming and they might seem redundant, as each model explains slightly different things, but at the same time they are all a part of the same whole. Once the first version of the storyboards were finished and presented, the interest picked up again. They were fairly quick to look through, and in a printed format notes could be scribbled on them when questions or thoughts arose. They ended up stimulating conversation regarding processes and work practices that that had been observed during the field studies. They were a simplification of the whole process, where the context of work was seen.

Experienced developers, who had also often visited customers, expressed surprise at how the work is actually done and started discussing different possibilities to support this type of behavior in LIMS. They also allowed for quick prototyping of the functionality the UI should provide to make the ideas more clear. Newman and Landay (2000) mention that storyboards are often used by designers a tool to convey ideas from scenarios and walkthrough models to others. Haesen et al. (2009) had similar results regarding the usefulness of storyboards in understanding the context as well as positive experiences from non-technical people who found storyboards easy to understand.

The strengths of storyboards seem to apply here, and that is to communicate requirements to a wide range of people and to help developers understand the broader context of the software. These are all desirable objectives from an agile development point of view (Chamberlain et al., 2006) and would therefore fit well into the processes at Software Point and therefore for LIMS development.

8.3 Final thoughts

The use of UCD and storyboards seem to fit well into the development of LIMS, but there are some questions that cannot be answered at this time. First of all, LIMS are big systems that get maintained and upgraded for many years. It is reasonable to assume that the benefits for both UCD and storyboards still apply for implementing the configurations for customers as shown by Viplola (2008) in the case of ERP systems (to communicate with customers and understand their processes better). Now, the critical thing here is that LIMS are not built often (Oinas, 2012). Perhaps a fresh start is needed every ten or fifteen years to make sure the technology is up to speed with current time. Even so, the functionality and processes of laboratories do essentially not change. A laboratory does what it has always done: Analyze samples.

There are therefore rarely any need to revisit the requirements of the users. There might be a better support for the workflow in laboratories now, and the workflow itself might differ from laboratory to laboratory, but in the end, little has changed in laboratories over the years (Oinas, 2012). Therefore it is safe to assume that experienced developers, who have visited laboratories and have an understanding of the work and culture that exists there, have all the information needed to create a new LIMS. However, there is always some evolution going as can be seen from some of the products that are currently being developed at Software Point or has been in the last few years. Some new aspects can always be found, not the least because of new technology that a new LIMS needs to support. A great example of this is the change from native clients to web-based applications.

The shortcomings of the existing systems that the new LIMS attempts to address are related to an old legacy of the products. They are native applications that has a lacking centralized data management. Moreover, there still new things to innovate based on what becomes feasible (for example an external view for customers, tablet-friendliness, etc.). Therefore, in fifteen years' time when technology and laboratories have leaped forward and there are no manual instruments anymore, then there is a time to go back to the laboratories before creating a new LIMS and ask what is going on here that is currently not sufficiently supported by a Software Point LIMS. UCD can be seen as a driver for innovation and storyboards as a way to communicate on an equal ground across the organization.

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A Contextual Inquiry checklist

Sample management

- Registering samples
- Importance of sample numbers
- Finding the right samples
- Changing of the status
- Different statuses
- Acceptance
- Complex searches
- Batches?
- When are samples entered or modified?
- How are different modes of entering a sample used? (Only one mode per lab etc.?)
- Priority?

Results

- Finding the right sample
- Entering the results
- Editing results
- Errors
- When are results entered or modified?
- Control samples?

Control

- Control samples?
- How are the results analyzed against the control samples?

Reporting

- What sort of reports?
- How are the reports sent?

Roles

- Organizational structure? Who interacts with LIMS and why?
- Who interacts with each other and why?
- Guidance for work?
- What tasks do people have? How are they carried out?

Registers

- What is kept in registers?
- How integrated is billing into LIMS?
- Customer information?

Other

- Tablet use
- Mistakes made
- Unused fields?
- most used features
- Is the workflow as it is because of the LIMS or because of the users or because some other processes?
- Artefacts

B Organized results example

Registering samples

Source doc [line#]	*Finding*
Company 1 [18-80]	some samples automatically from Company 1 through stock management
Company 1 [81-172]	a product group has readily defined tests
Company 1 [702-811]	some samples entered manually (from customers) check results visually, accept results, print results, enter results into LIMS (a 4th way to enter sameples)
Company 1 [1114-1152]	paper for listing samples and results
Company 1 [1403-1474]	list of sample info/as a check list for what needs to be added to LIMS
Company 1 [1920-1962]	analysis requests, by phone, mail, e-mail
Company 1 [1975-1993]	recieves packages (secretary)
Company 1 [1994-2036]	internal samples registered automatically
Company 1 [2037-2081]	e-mail with entered sample that will arrive
Company 1 [2338-2442]	has to wait for some time before changing info before it prints. If changing mid-print print might fail
Company 1 [2443-2475]	manually enters outside samples
Company 1 [2476-2526]	sample number seems important (used all the time)
Company 1 [3194-3306]	sample entering by web for customers? lacking expertise, but could generate a standard list based on drink info
Company 1 [3426-3452]	add requests for analysis
Company 4 [0-135]	two ways to use LIMS, one to register samples "buy-in" adds samples/requests
Company 4 [137-186]	buyers ask for analysis, by adding samples into the system registrations are also done by lab-people as well
Company 4 [188-364]	seeing what "artikel" belongs to what, type of sample have been problematic, instructions for entering samples
Company 4 [2899-2984]	weekly errors in entering samples from the buyers (in production) most samples are imported into LIMS, if there's only one sample it's manually entered
Company 4 [2986-3039]	ability to enter many sample results at the same time
Company 4 [3201-3423]	many different levels for creating new artikels (products?), need to specify the product, analysis, analysis profiles and then connect to each other through a new view. SHould be streamlined with for example with a wizard.
Company 4 [3450-3570]	would like to have models for entering samples (so that there's a model where only one or two fields need to be updated)
Company 3 [103-187]	sysadmins can change batches, change regsiters, create control samples, manage users
Company 3 [189-237]	laborants reg samples, results, control samples
Company 3 [748-840]	plan the work weekly, 2 admin positions who reg samples and send results and accept results
Company 3 [1148-1198]	samples are first entered, before anything is done
Company 3 [1258-1281]	registration takes long
Company 2 [109-247]	Single samples for research are usually entered into Excel because calculation in LIMS is percieved difficult (also resistance to change)
Company 2 [290-326]	automatic adding of samples as well
Company 2 [380-395]	laborant enters results
Company 2 [433-445]	laborant adds samples
Company 2 [446-498]	adds control samples and updates limits if nessecary

Figure 3: Example of the way the information was organised after categorization.

C Flow model examples

C.1 Company 1 flow model

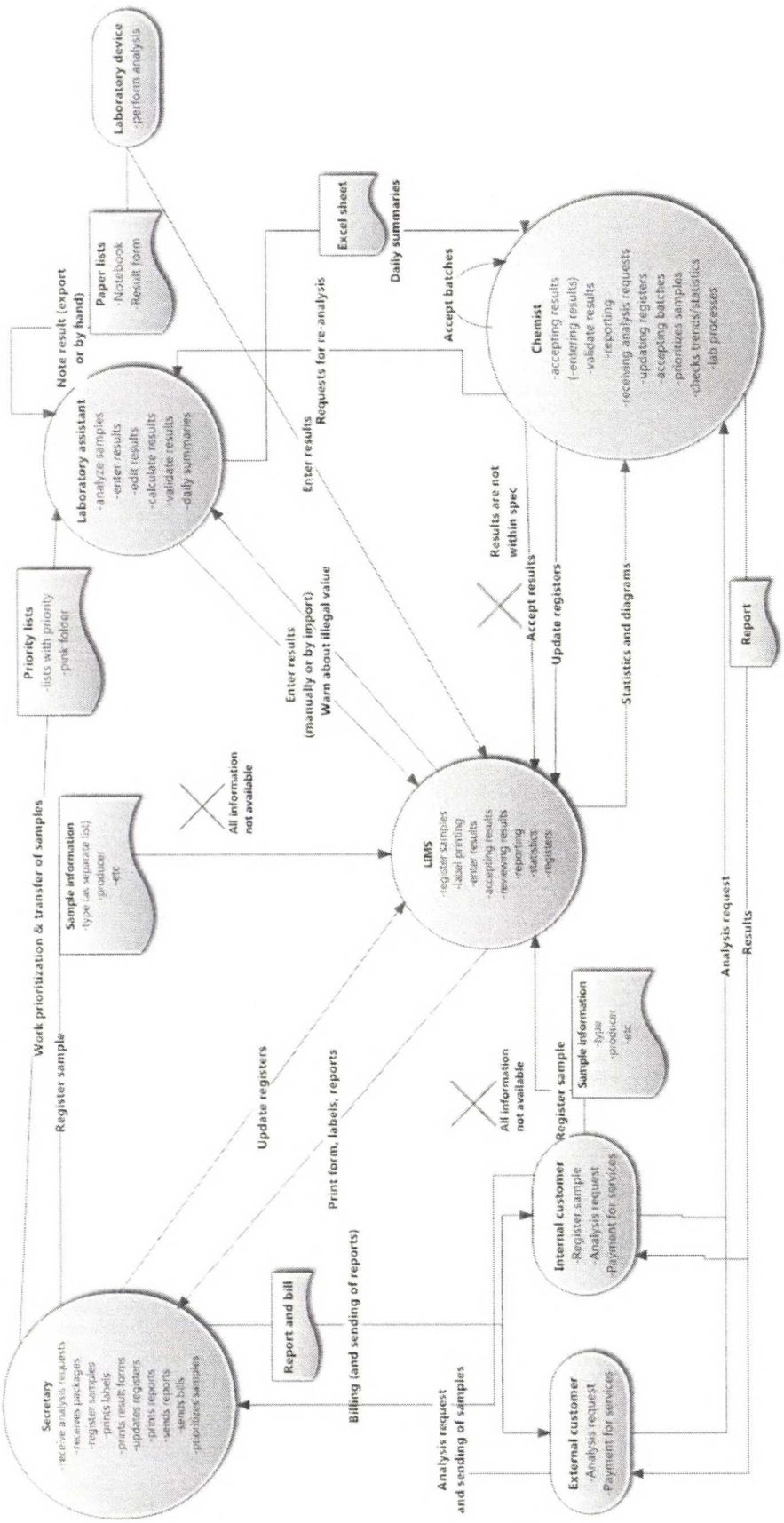


Figure 4: Company 1 flow model.

C.2 Summarized flow model

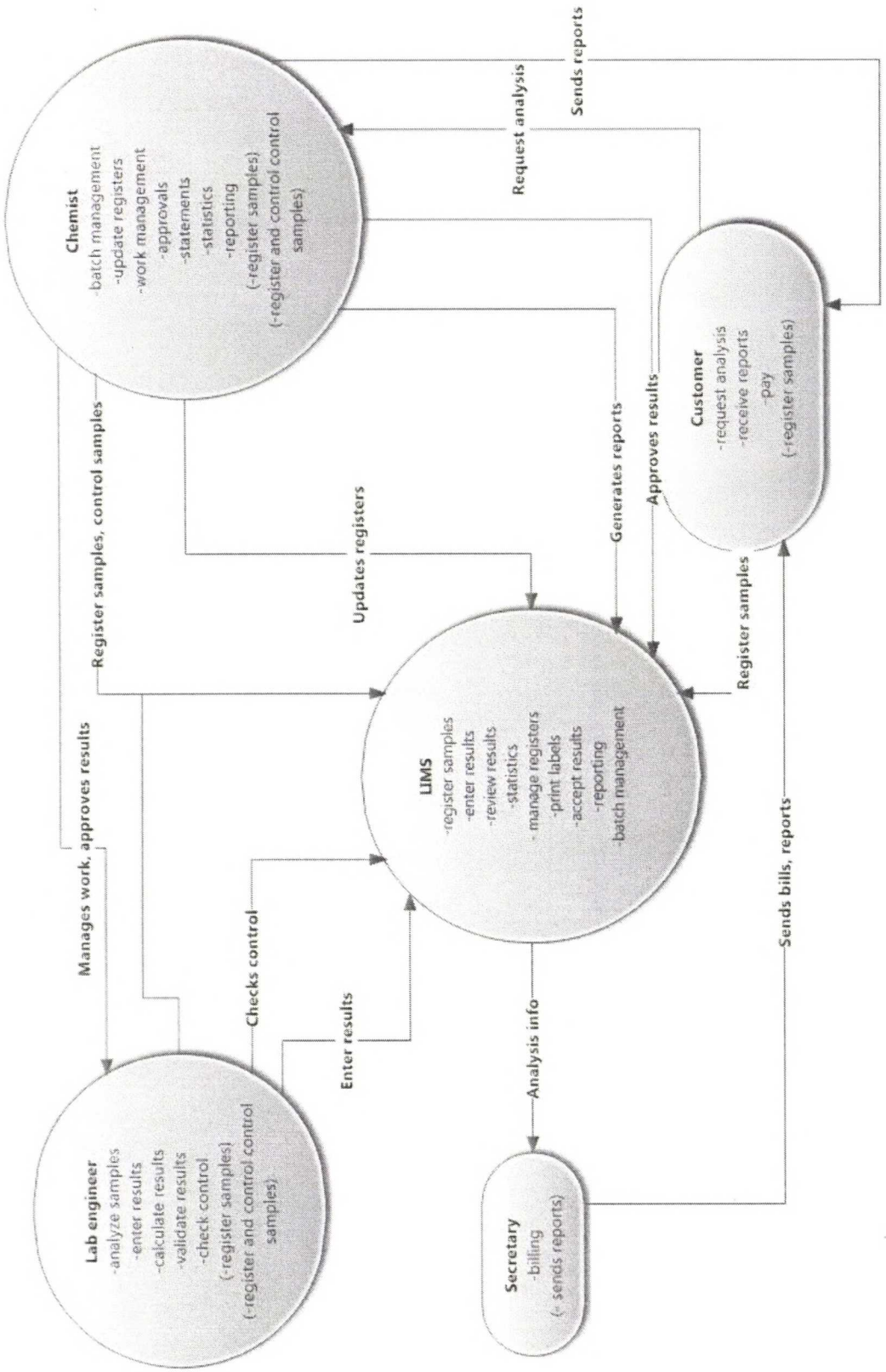


Figure 5: Summarized flow model.

D Sequence model examples

D.1 Company 1 sequences

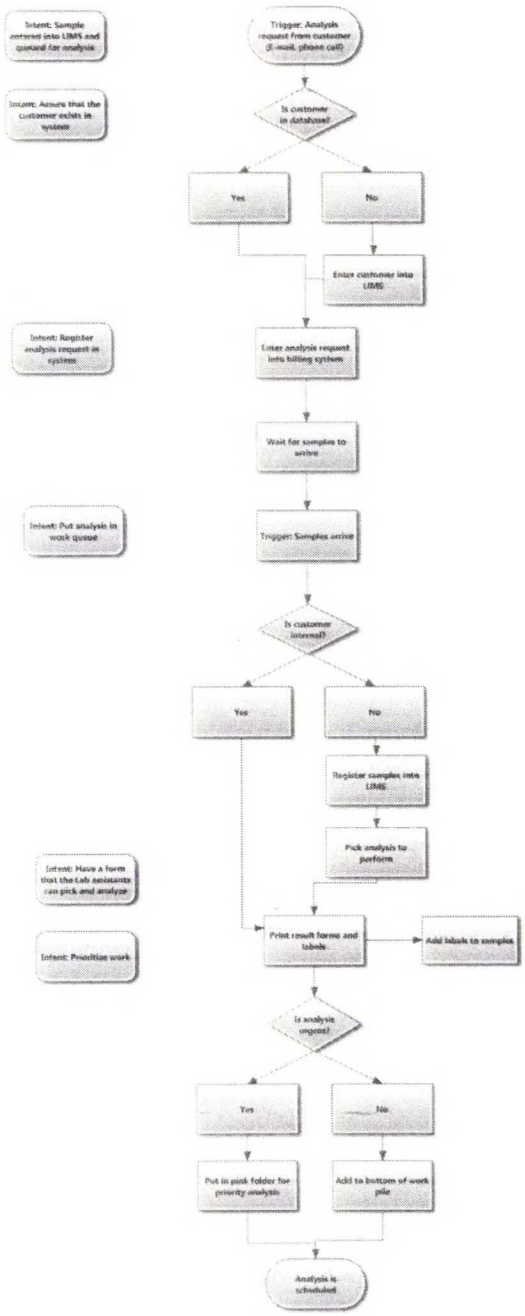


Figure 6: Registration sequence model example from company 1.

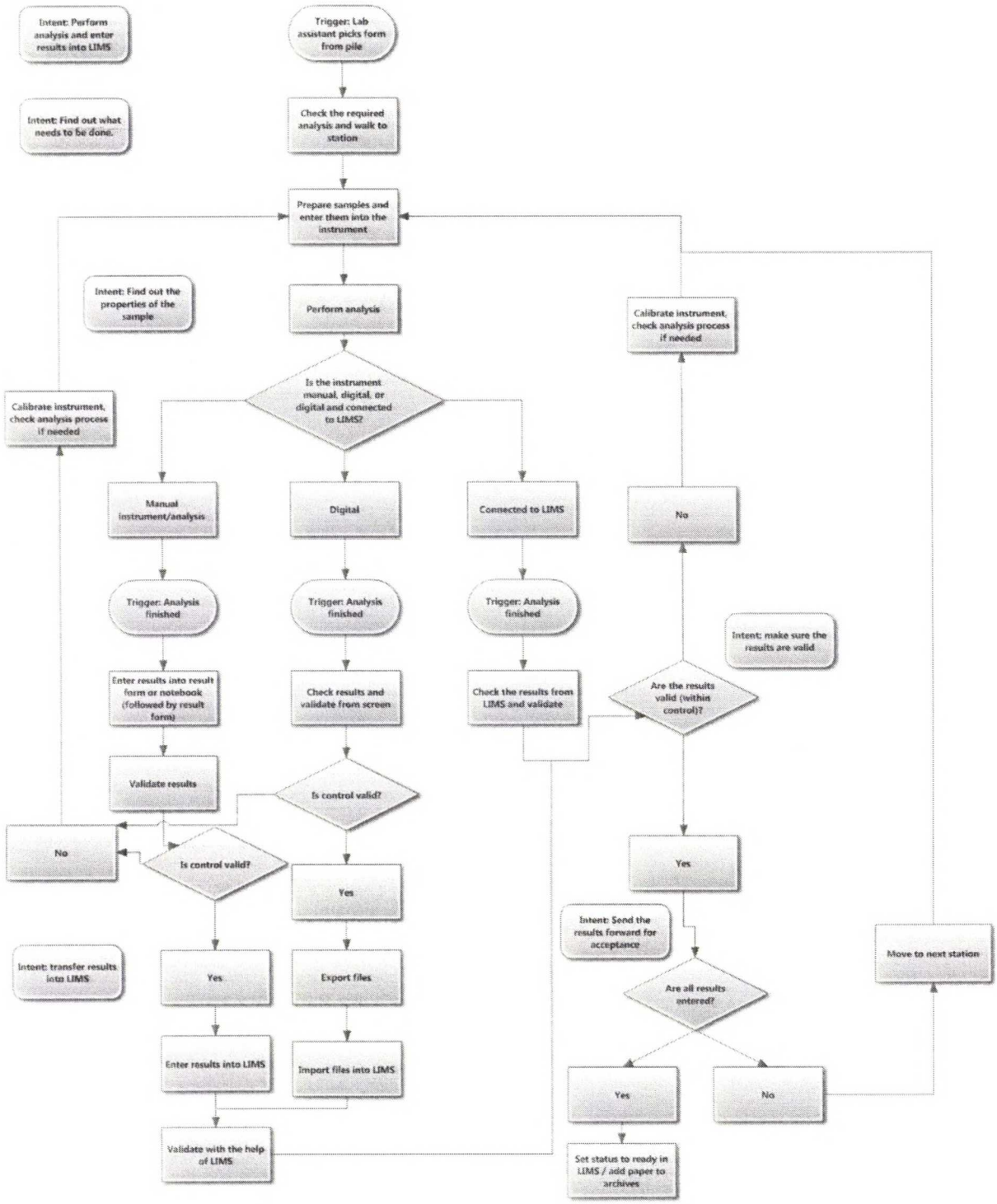


Figure 7: Analysis sequence model example from company 1.

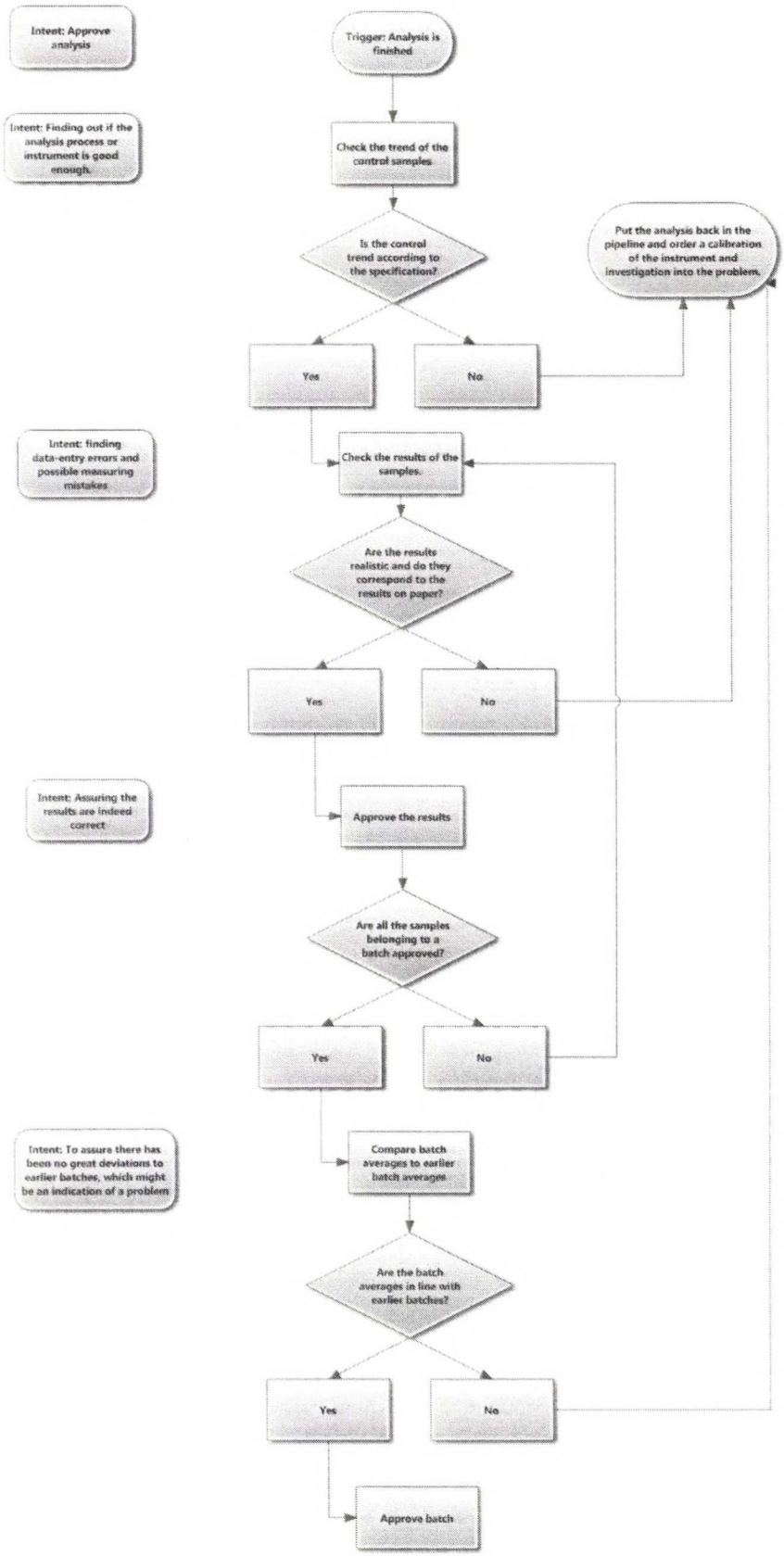


Figure 8: Sample approval sequence model example from company 1.

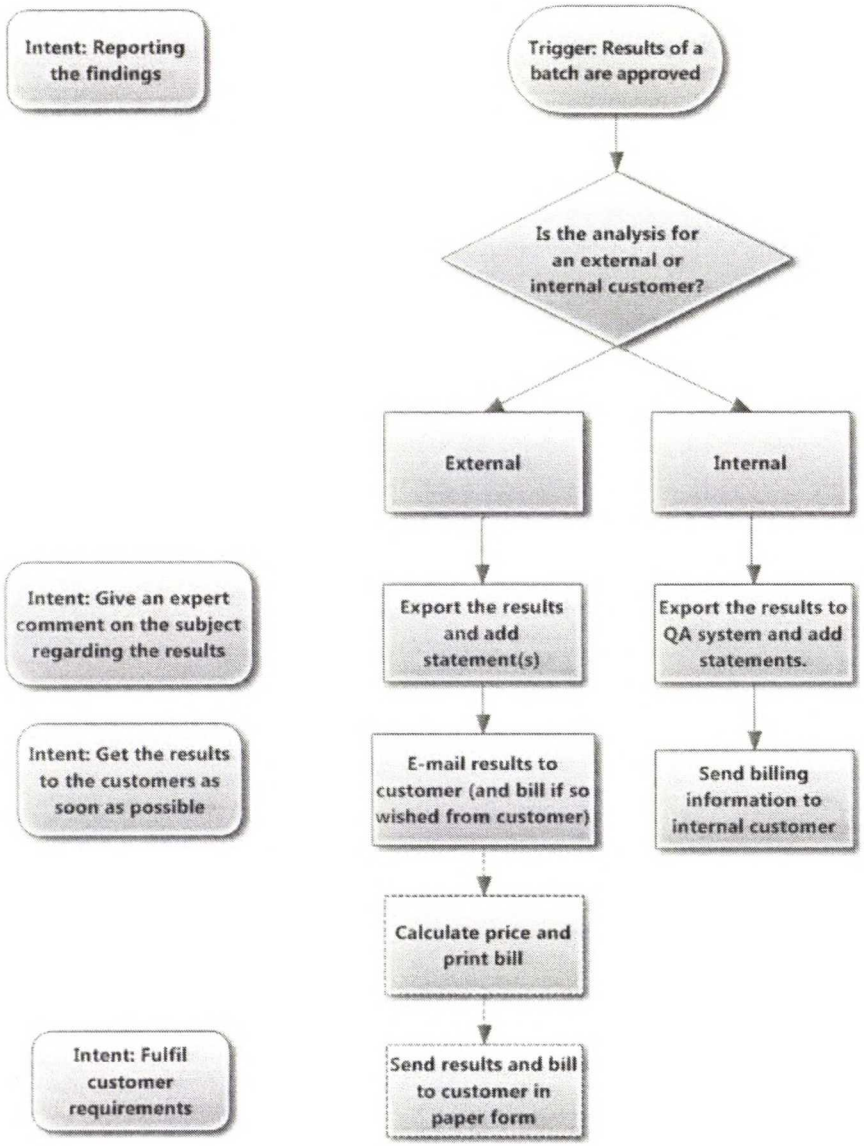


Figure 9: Reporting sequence model example from company 1.

D.2 Summarized sequence for registration

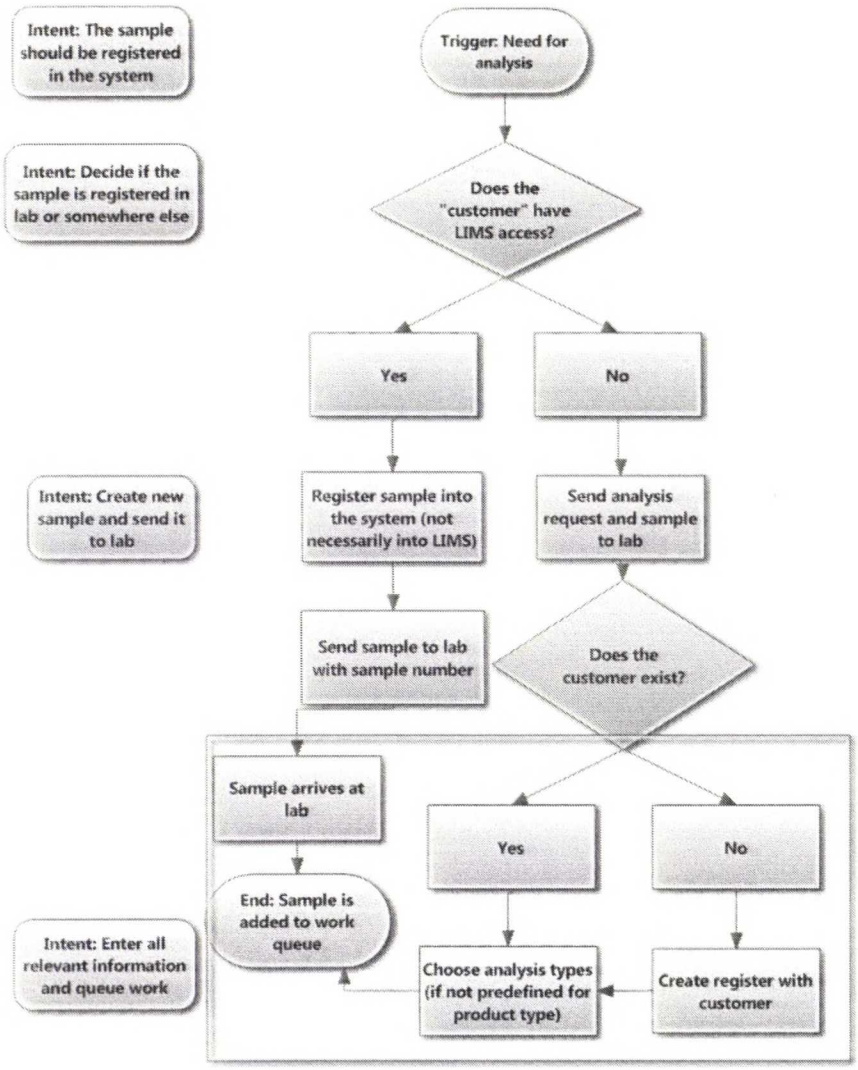


Figure 10: Summarized sequence model for registration.

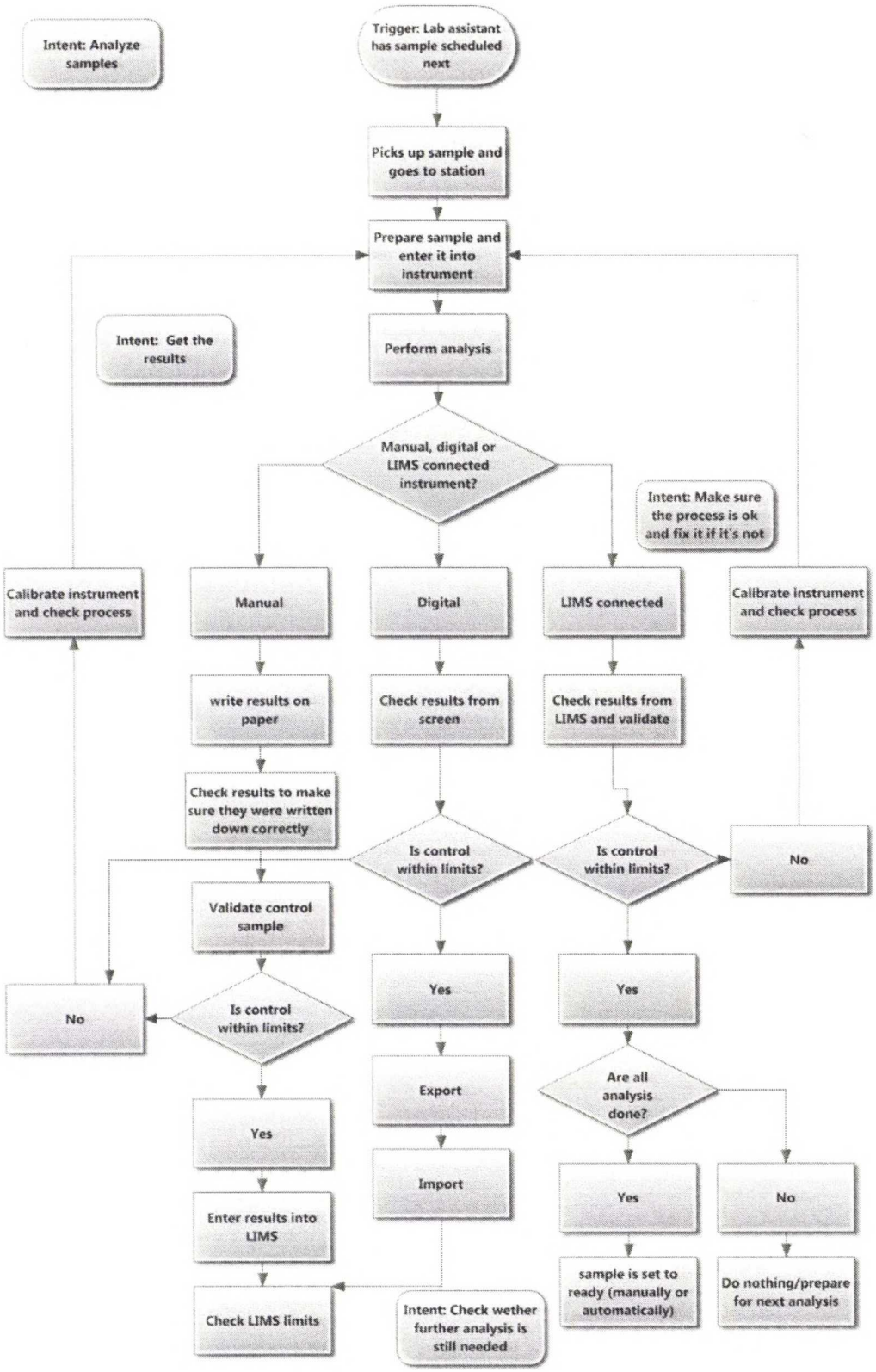


Figure 11: Summarized sequence for analysis.

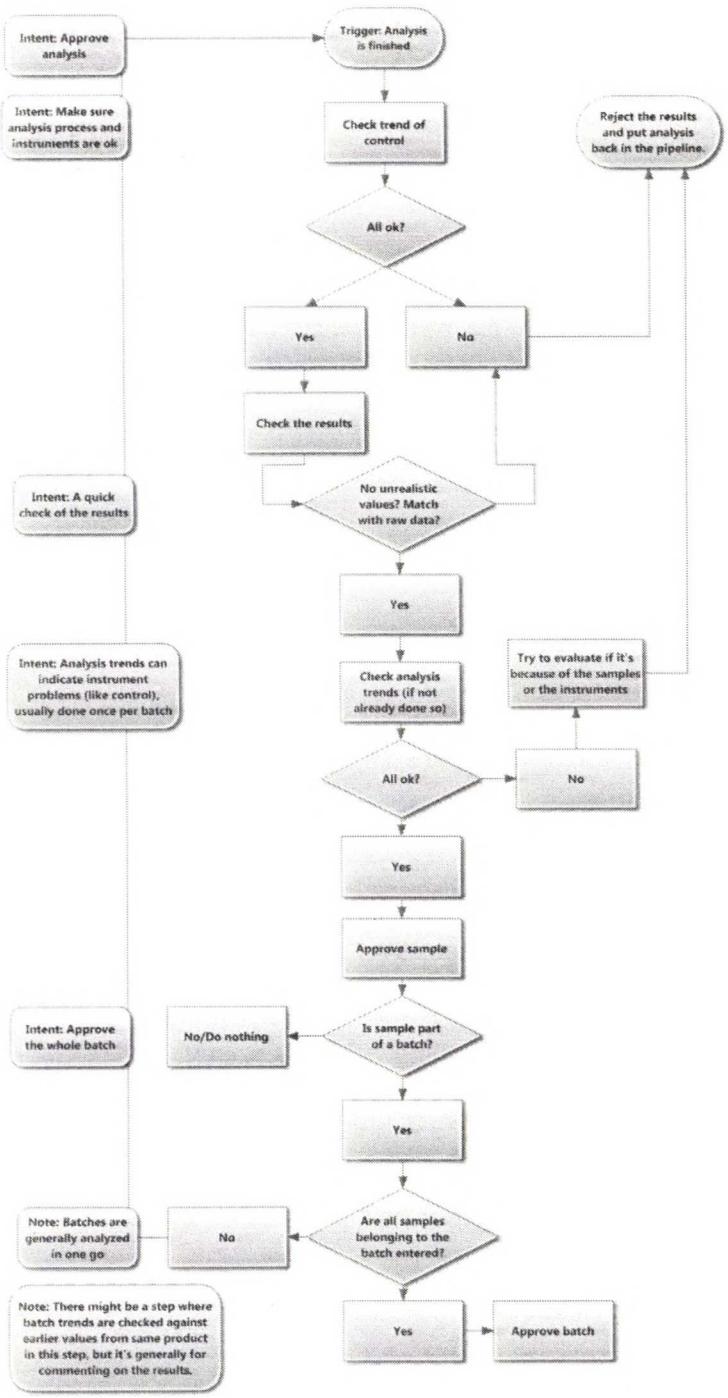


Figure 12: Summarized sequence for acceptance.

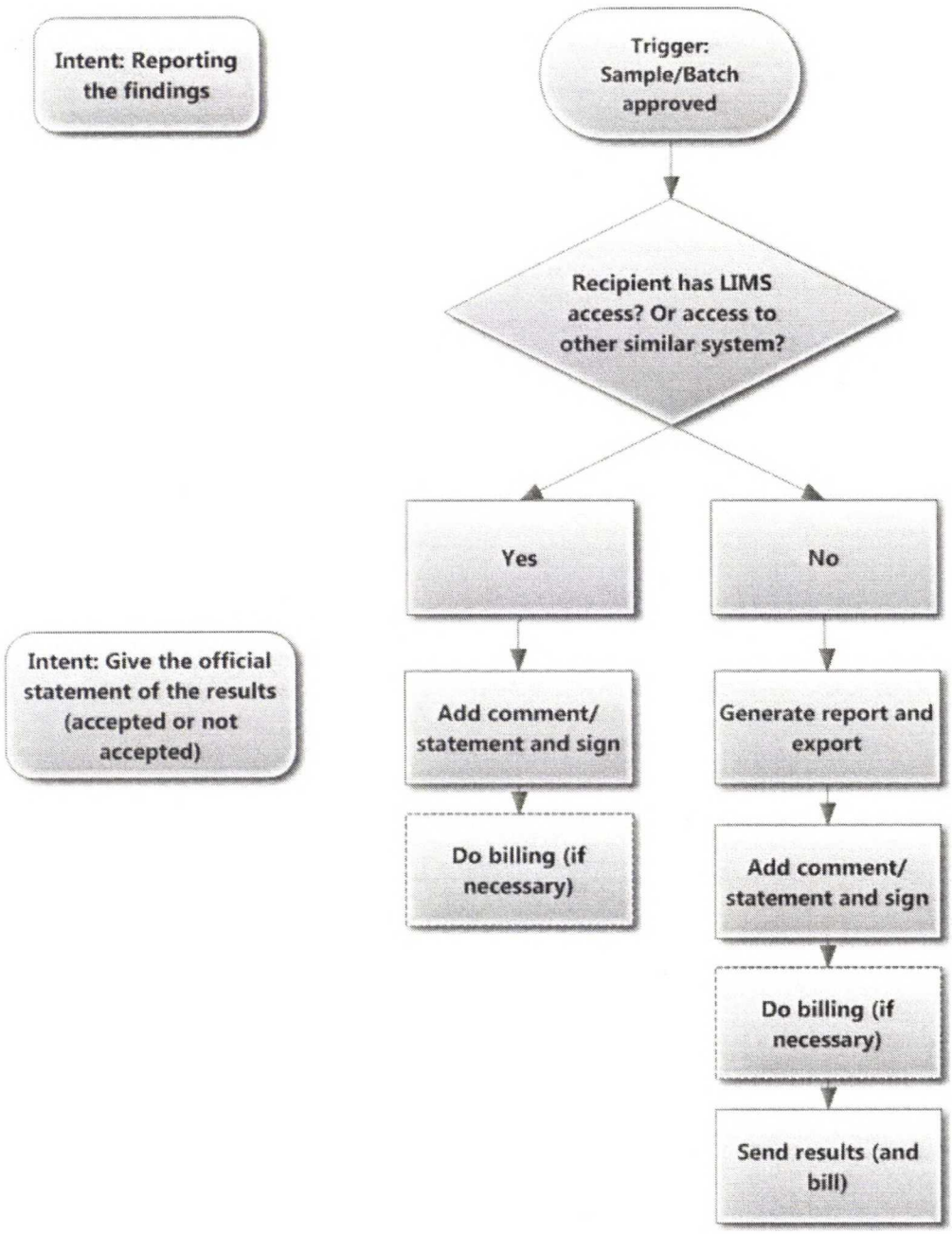


Figure 13: Summarized sequence for reporting.

E Cultural model example

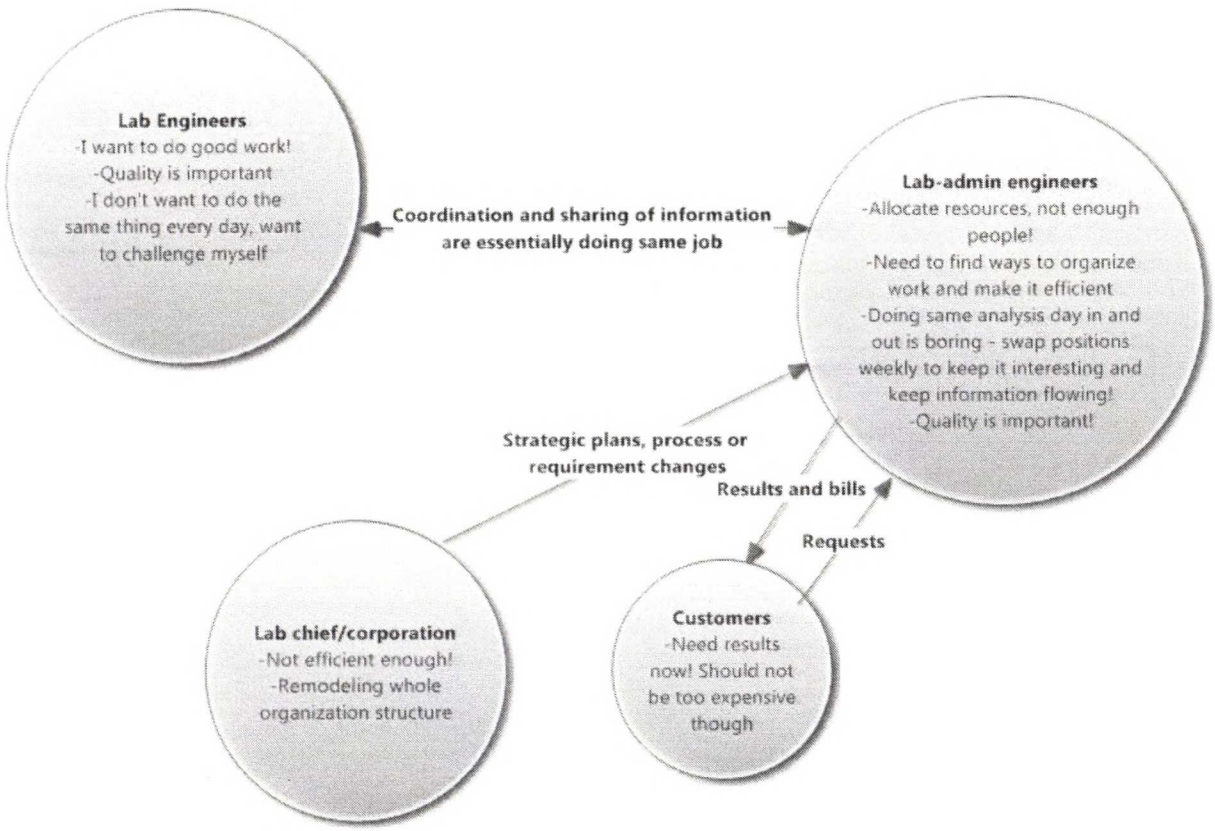


Figure 14: Cultural model example from company 3.

F Physical model example

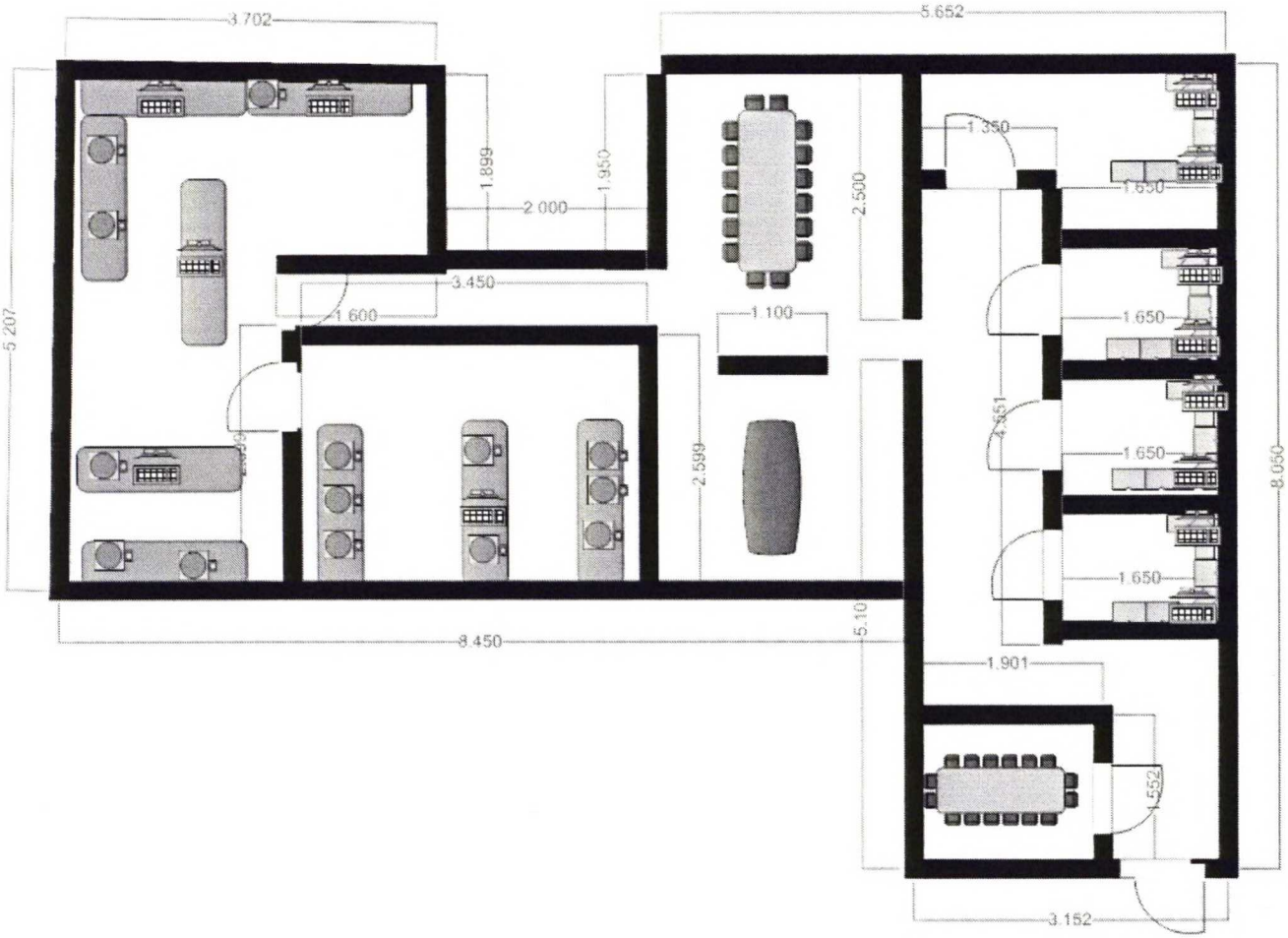


Figure 15: Physical model example from company 4.

G Affinity Diagram

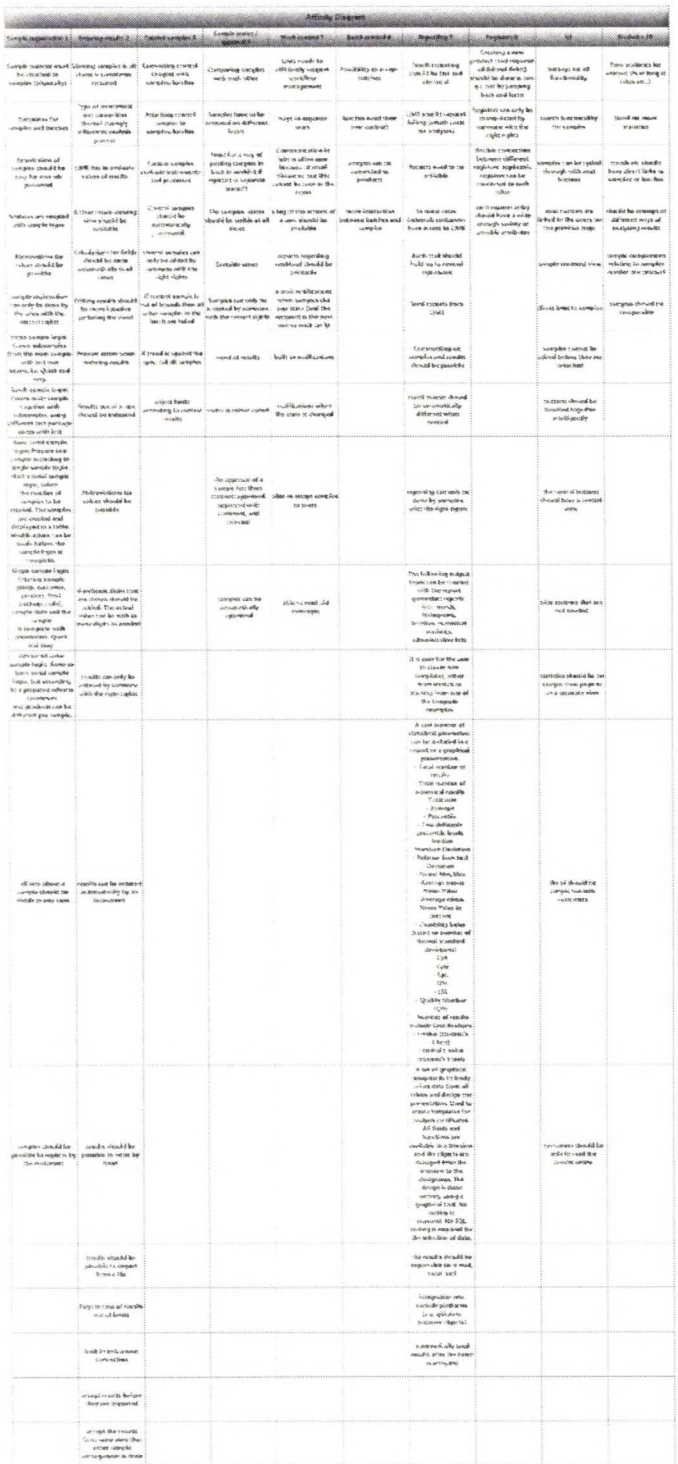


Figure 16: Affinity diagram.

H Consolidated sequence models

H.1 Consolidated sequence model for registration

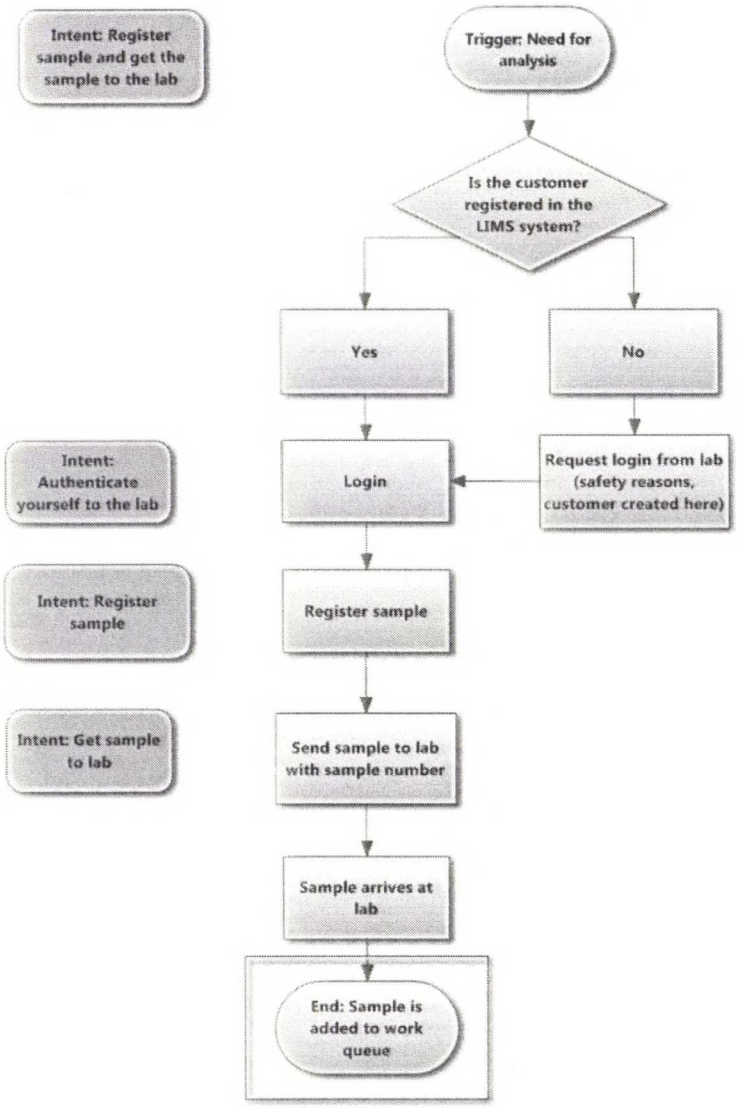


Figure 17: Consolidated registration sequence.

H.2 Consolidated sequence model for analysis

Figure 18: Consolidated analysis sequence.

H.3 Consolidated sequence model for acceptance

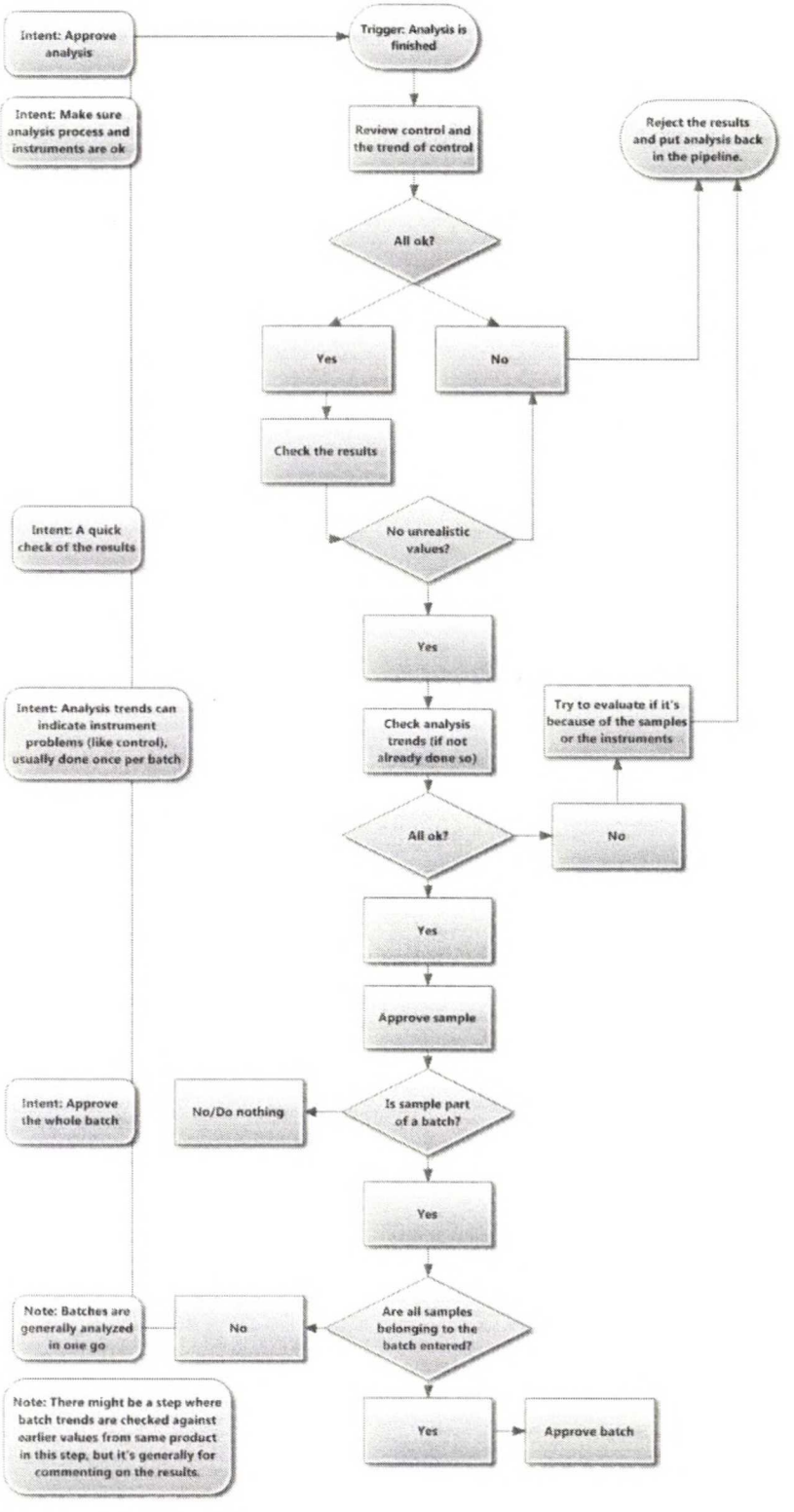


Figure 19: Consolidated approval sequence.

H.4 Consolidated sequence model for reporting

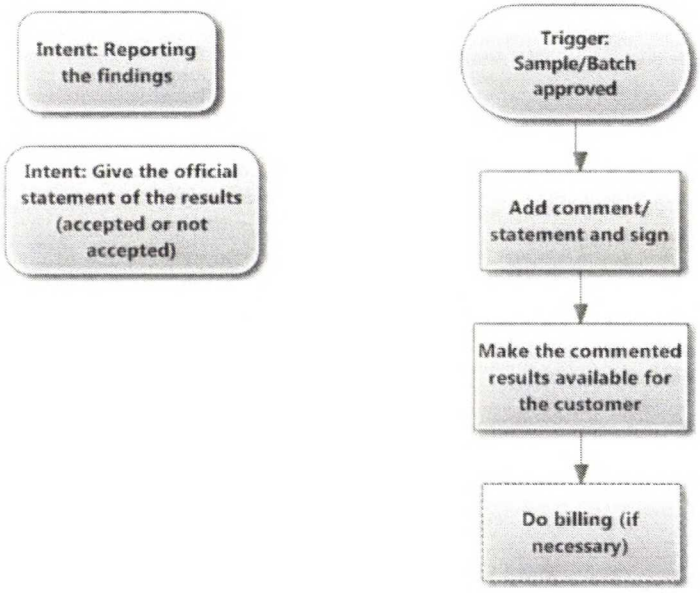
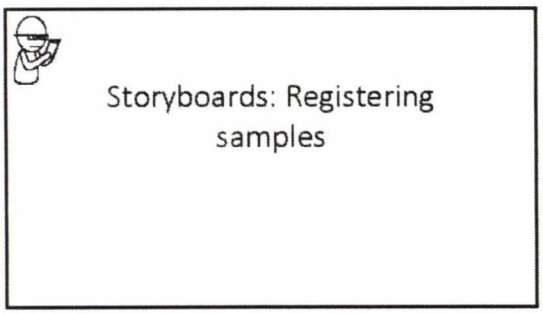
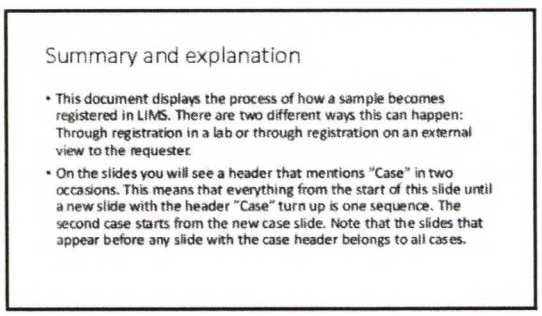


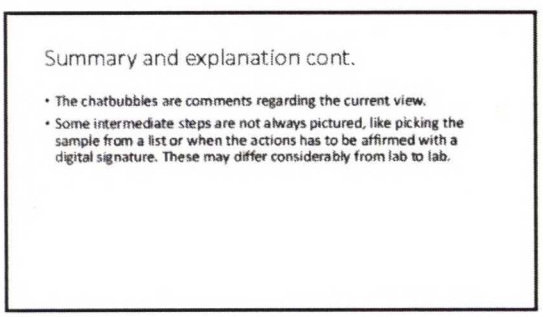
Figure 20: Consolidated reporting sequence

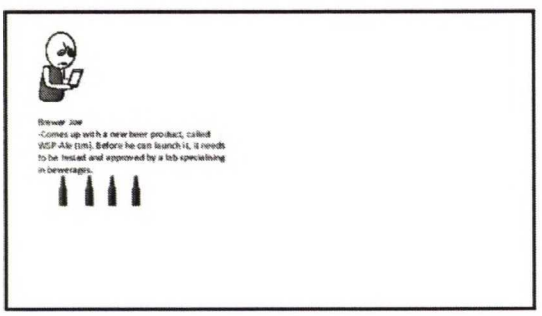
I Storyboards

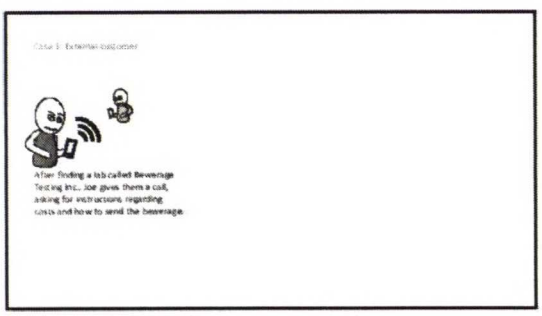
9/6/2012

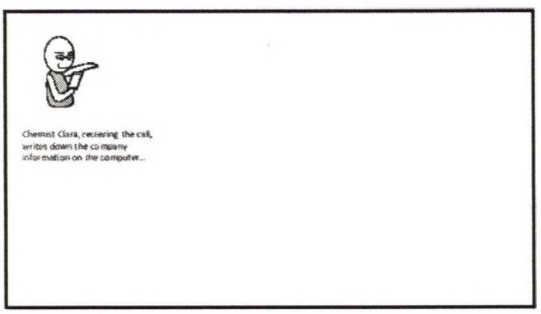






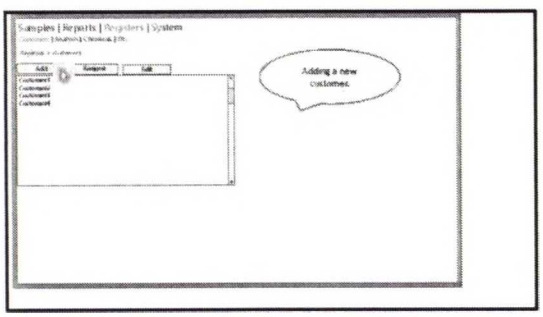


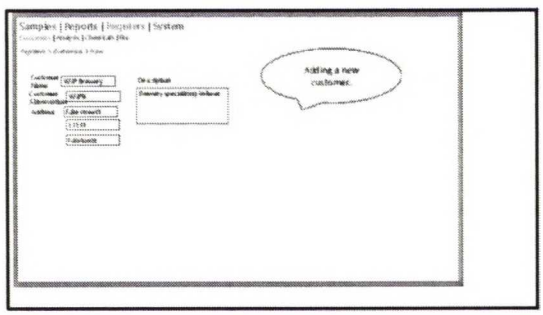


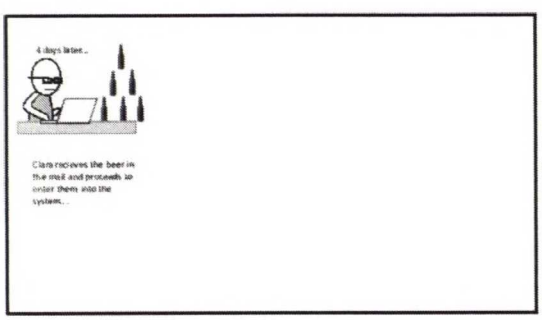


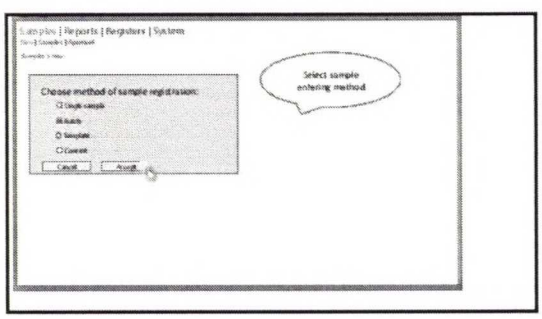
1

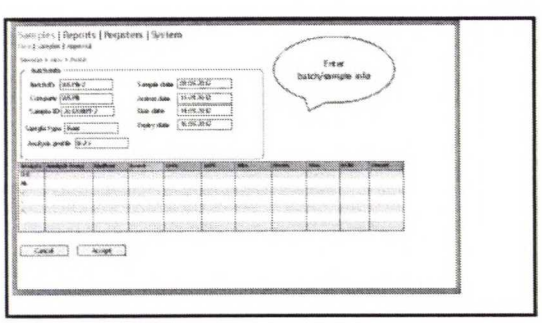
Figure 21: Storyboard slides 1-6.











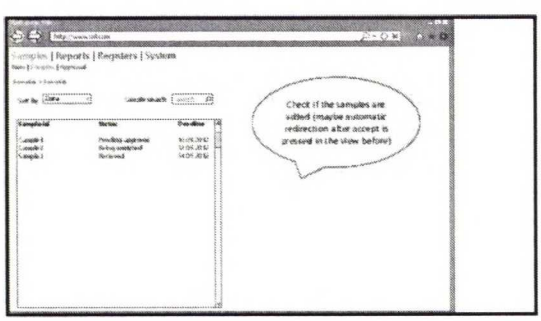
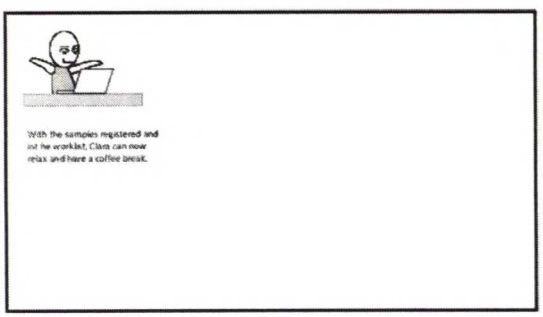
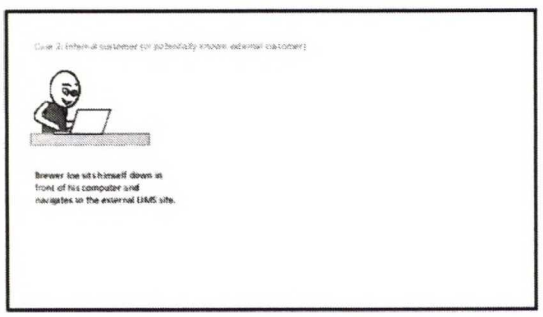
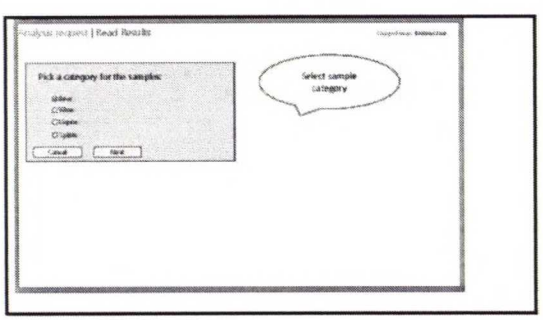
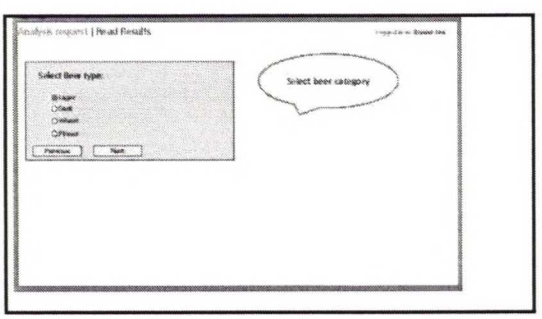


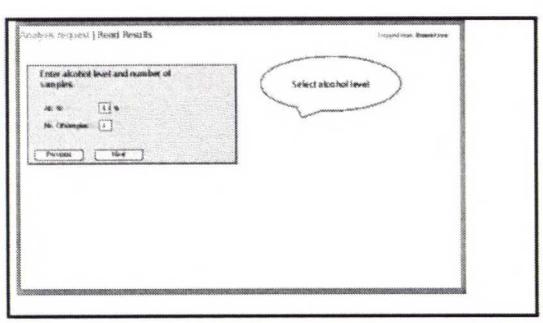
Figure 22: Storyboard slides 7-12.











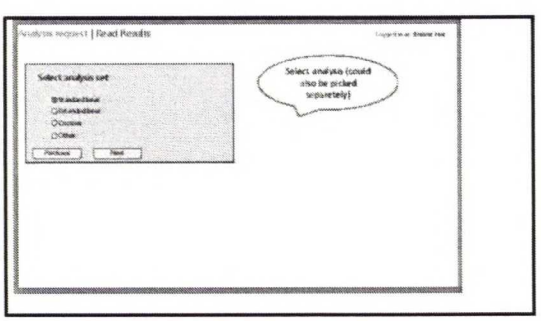


Figure 23: Storyboard slides 13-18.

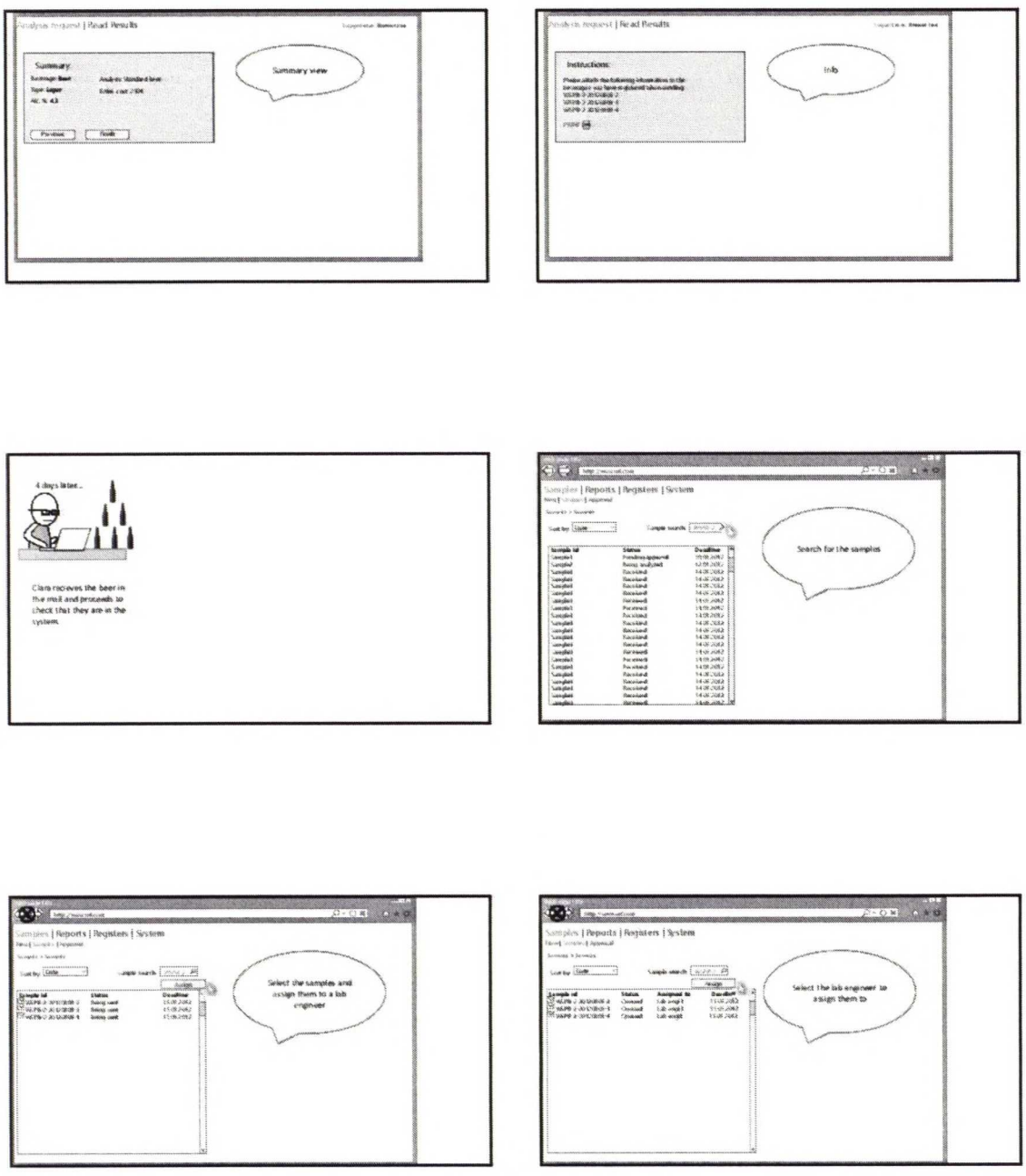
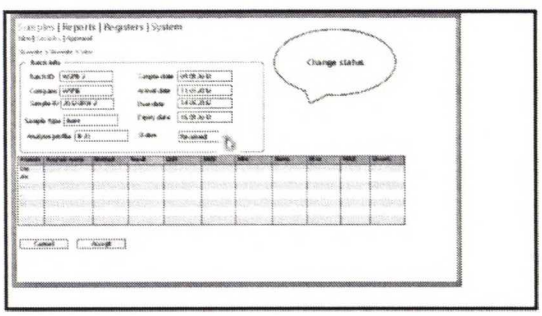


Figure 24: Storyboard slides 19-24.



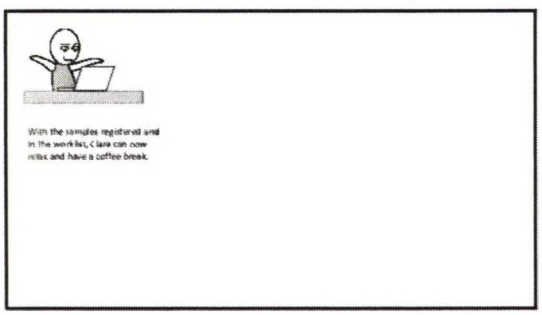


Figure 25: Storyboard slides 25-26.